THE COLLIERY FIREMAN AND HIS DUTIES

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FOREWORD

NOBEL INDUSTRIES LIMITED, through its constituent companies, is responsible for the major portion of the Blasting Explosives and Accessories produced in the United Kingdom. It is the constant aim of the Company to improve quality, to reduce prices, and to give special service to users by expert guidance on the best methods of blasting. In pursuance of this latter purpose, Nobel Industries has pleasure in offering to the Colliery Trade "The Colliery Fireman and His Duties," which is designed to set out in convenient form and in simple and concise language the duties and responsibilities of that important colliery worker.

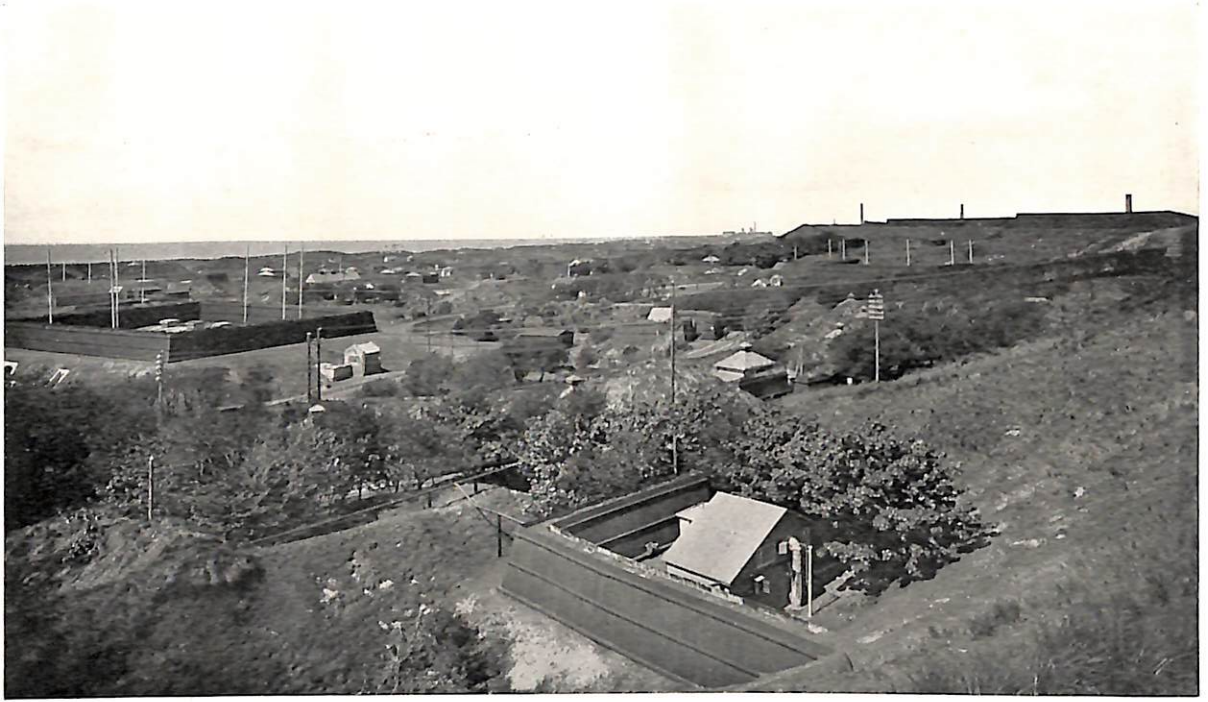
Whilst it is recognised that no publication however detailed can replace practical experience and the excellent teaching of the Mining Schools and Institutions, the Company believes that, in addition to Firemen or aspirants to that post, Colliery Owners, Managers and Officials generally, and Professors and Teachers, will welcome this book. From limitation of space considerations the book has been confined to matters more closely allied to the use of explosives, and consequently such a subject, for example, as Timbering, admittedly of supreme importance, has not been included. The book therefore is issued without claim as to completeness in respect of every branch of the Fireman's duties.

The preparation of the book and the work of revision have been carried out by experienced men and

competent authorities, whose valuable services are hereby gratefully acknowledged, but notwithstanding the care which has been taken the Company must disclaim responsibility for absolute accuracy in every detail. The thanks of the Company is due also to the Government Departments, *i.e.* H.M. Inspectors of Explosives, H.M. Inspectors of Mines and H.M. Stationery Office, who have assisted in various ways, and to the firms who have supplied data and illustrations of Safety Lamps and other appliances.

The book has been arranged in the sequence which it is thought will be most convenient to the reader without regard to the commodities in which the Company is particularly interested. The section relative to the use of Explosives and methods of Shotfiring commences on page 49. Attention is also directed to the notice on the cover regarding other printed matter which may be obtained on application.

The importance to Colliery Firemen and Colliery Officials generally, of keeping fresh in the knowledge of the subject, cannot be exaggerated. If in any way this publication assists to that end, and thereby increases the efficiency and safety of coal mining, its purpose will be well served.



Nobel Industries Ltd. Ardeer Factory, Stevenston, Ayrshire.
View from nitro-glycerine hill. The factory covers an area of 1,000 acres.

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Chapter I

QUALIFICATIONS, APPOINTMENT AND ROUTINE WORK

In all coal, stratified ironstone, shale, and fire-clay mines, there must be appointed in writing by the Manager, one or more competent persons to make such inspections and carry out such other duties as to the presence of gas, ventilation, state of the roof and sides and general safety (including the checking and recording of the number of persons under his charge) as are required by the Coal Mines Act (1911) and the regulations of the mine. These persons are called firemen, examiners, deputies, or, in parts of Scotland, inspectors, according to usage in different districts. For convenience they will be referred to throughout this book simply as firemen.

The fireman's duties enumerated above are referred to as his statutory duties, and except in the case (*a*) of mines employing a total of less than 30 men below ground, (*b*) of mines in Durham and Northumberland, or (*c*) of a mine specially exempted by the Inspector of the Division, he must devote his whole time to such duties, though he may fire shots or measure work done provided this does not interfere with his statutory duties.

Mines are usually divided into districts or sections, with a fireman appointed to each. These districts must not be of such a size, and other duties must not be of such a nature, as to prevent the fireman from carrying out all his statutory duties in a thorough manner.

APPOINTMENT AND QUALIFICATIONS OF FIREMEN

The conditions governing the appointment of a fireman are that he must be 25 years of age or upwards, he must have a certain amount of practical experience, and possess a fireman's certificate. The underground practical experience necessary is five years, of which not less than two years have been at the working face. The holding of a colliery manager's first or second class certificate qualifies a person to be appointed as a fireman.

FIREMAN'S CERTIFICATE

The examination for the fireman's certificate requires that the candidate be able to make accurate tests for inflammable gas so far as

this can be done with a safety lamp, and that he can do this with any of the various types of safety lamp, and with any of the various kinds of oil in use in the district in which he is employed. He has to show the examiner that he understands the method of detecting inflammable gas by means of a safety lamp, and that he can judge by the size and appearance of the gas cap on the flame how much gas approximately is present. A candidate is tested with percentages of gas from 2 per cent. upwards and must be able to detect a 2 per cent. cap. Glasses may be worn when making the observations, but it rests with the examiner to decide whether the eyesight is so defective that under the working conditions in a mine a candidate would not be able to make accurate observations.

A candidate is required to show that he can measure the quantity of air in an air-current, first, by measuring the speed of an air-current, both by means of an anemometer and by observing the speed at which dust or smoke is carried by the air, and, second, by calculating from measurements the cross-sectional area of an air way or gallery. Air-measurements and the testing for inflammable gas are dealt with more fully later in the book.

The candidate's hearing will be tested, and it must be such as to enable him to carry out his duties efficiently. This does not mean that a fireman must possess a standard of hearing above that of the average man, nor is it required that his hearing must be up to the standard in both ears. If the candidate is able to hear sounds audible to the average man it would be sufficient.

If the candidate is employed in a mine in which inflammable gas is unknown he is not required to pass the gas test, but if at any time he obtains employment in a gassy mine he will require to submit himself for examination in this test.

The fireman's certificate can only be obtained from one of the approved Mining Schools, Institutions or Authorities, a list of which appears on page 77. The scale of fees for the examination is as follows:

For full examination, *i.e.* gas tests, air-measurements and hearing - 7/6

For two parts only, *e.g.* gas tests and hearing - 5/-

For one part only - 2/6.

The Act provides also for further certificates as to eyesight and hearing being obtained by a fireman at intervals of five years. The

object of these further certificates is to ensure that a fireman's eyesight continues to be such as to enable him to test for gas, and that his hearing remains good. The first of these certificates will not be required until the expiration of five years from the date on which he gets his fireman's certificate. This five-yearly certificate can be obtained either from one of the Approved Schools, Institutions or Authorities or from a doctor selected by himself. The fee for obtaining this certificate will be payable by the fireman's employer.

THE FIREMAN'S ROUTINE WORK

At the entrance to each fireman's district there is an appointed station beyond which no workman is allowed to pass until the district has been examined. Each district must be inspected and reported on by a fireman in the two hours immediately preceding the commencement of a shift. In some pits the inspection preceding a shift is carried out by the fireman going off duty, and in this case he must give all the information to the oncoming fireman to enable the latter to instruct the workmen on his shift as to their places of work, and as to any special precautions to be observed by them, unless he is able to meet the workmen and instruct them personally as to the state of the places. The general practice is for the fireman to start work two hours before his shift of workmen comes on; he is then in a better position to give the necessary instructions.

The inspection is of great importance and must be carefully carried out. All roads and working places, including places temporarily stopped, must be examined as to the state of the ventilation, the condition of the roof and sides and the general safety. Except in a case where inflammable gas is unknown the inspection must be made with a locked safety lamp, and no other light may be used during the inspection. Frequent tests for gas should be made and these must be done with due care lest the fireman "lose his light" and be required to return in the darkness to the re-lighting station, or to remain until another fireman can be found to come and search for him. The face of the brushing, or ripping, in every working place should be tested with the safety lamp, as this is a place where gas is often found.

In every mine there are timbering regulations stating the maximum distance between props, between the front line of props and the face, and between chocks. Where the coal is holed either by hand or machine, the distance between the holing sprags must not exceed

6 feet. The fireman must see that these regulations are adhered to and make a note of any fault in this respect. The position of falls must be noted and the nature of the repairs necessary. If he finds any place in a dangerous condition, either from gas or any other cause, he must securely fence off all approaches to such place and mark it with a danger signal. Mention must be made of this when filling in his report.

He should see how his district is placed with regard to timber supply, both in the working places, and in the pass-byes, sidings, etc.

On the completion of his inspection, the fireman returns to his appointed station and fills up his report form. A specimen form is shown in Appendix III.

By this time the workmen are coming forward and he gives them any instructions as to their working places that may be necessary. He instructs repairers and roadmen as to work requiring immediate attention. Where safety lamps are in use these are examined externally before the workman pass the station, to see that they are in safe working order and securely locked. The number of workmen under his charge is checked and recorded in his report.

A great deal of the work of running the district devolves upon the fireman, and though he must give first consideration to his statutory duties, he is expected to see that the work of producing coal and the execution of repairs are properly carried out in the economic interests of the colliery, as well as in the interests of safety.

Two more inspections, similar to the first, must be made during the workmen's shift, but the first of these need not be reported on, and the second is often carried out by the relieving fireman. In this case it is necessary for the fireman on duty to confer with the relieving fireman before he leaves the mine. In the case of a mine worked by a succession of shifts, no place shall remain uninspected for an interval of more than 5 hours.

The fireman's second inspection occupies, as a rule, more time than the first, and attention is paid to many details in the working of the district. Tests for gas should be made from time to time at the face of the coal and of the ripping, and also at the edges of the waste or gob. The condition of the roof in the waste should be observed, and precautions against undue crush taken. Brattice and air-pipes should be extended, where necessary, to ensure an adequate supply of fresh air at the working faces. Ventilation doors must be maintained

so that they will fall to and close automatically, and it is the fireman's duty to see that this is done. The state of the district as to coal dust and accumulations of water should be noted. If the fireman finds any of the ropes, chains, signals, brakes, etc., in his district to be in an unsafe condition, he must stop their use. If any damage to a safety lamp in his district is reported to him or comes to his notice, he must ascertain and record in his report the cause and nature of the damage.

All accidents and dangerous occurrences which come to his notice must be reported to a superior official. During his second round the fireman will probably be called on to fire shots; the regulations and recommendations in this connection are dealt with in a separate part of this book.

The fireman has power to send out of the mine any workman under his charge who commits an infringement of the regulations, or fails to carry out any directions given him with regard to the safety of the workman himself or any other person. Such misdemeanour *must be reported in writing* to the Manager or Under Manager at the end of the shift.

Chapter II

GASES FOUND IN THE MINE

In order that the fireman or shotfirer may appreciate the necessity for good ventilation in his district, it is necessary for him to know something of the various gases which are found in the mine both in normal and in abnormal times, and their behaviour under certain circumstances. A brief survey of the gas laws is given in Appendix 1, page 75.

Atmospheric air under ordinary circumstances is made up of a mixture of nitrogen and oxygen, and a very small amount of some rarer gases. For practical purposes the mixture may be regarded as containing 79 per cent. nitrogen and 21 per cent. oxygen, by volume.

Nitrogen is an inert gas which does not support life or combustion, and merely acts as a diluent in air.

Oxygen is a widely distributed element, and is found in the free state in air and in combination with many other elements. It is a colourless and tasteless gas, and has no smell. It is an active supporter of both life and combustion. It is the most important to man of the gases in the air, and variations from the normal air content of 21 per cent. cannot be neglected. As the amount of oxygen falls the breathing becomes faster and deeper, and men breathing air that has as little as 15 per cent. usually become dizzy, have a rapid heart beat, and often suffer from headache. Concentrations above the normal of oxygen in air do not show a marked physiological effect. It has been shown that irritation of the lungs is only found after 48 hours of continuous exposure to an atmosphere containing over 80 per cent. oxygen.

The Coal Mines Act (1911) states that "a place shall not be deemed to be in a fit state for working or passing therein if the air contains . . . less than 19 per cent. of oxygen."

Contamination of mine air is caused by the presence of certain gases which are either poisonous in themselves, or cause a deficiency of oxygen in the atmosphere. Contaminated mine air usually contains one or more of the following gases, viz. carbon dioxide, carbon monoxide, methane, or sulphuretted hydrogen. Water vapour also has a harmful effect on the atmosphere, particularly where the temperature is high.

CARBON DIOXIDE (CO_2)

This is a colourless, odourless gas having a slightly acid taste. It does not support combustion or respiration. Some authorities say that although it is not nearly as poisonous as the monoxide, it still has a direct poisonous effect upon the system, and sickness or death caused by this gas may not be entirely due to the absence of oxygen. It is a heavy gas, being a little more than $1\frac{1}{2}$ times the weight of air; on account of this it is most often found near the pavement in dip workings or in sumps.

According to the Coal Mines Act "a place shall not be deemed to be in a fit state for working or passing therein if the air contains . . . more than $1\frac{1}{4}$ per cent. of carbon dioxide."

Carbon dioxide is sometimes called stythe, choke-damp, or merely "damp," and is produced in the mine by explosions, where it appears in the afterdamp, by underground fires, by the oxidation of coal and other substances, and by exudation from the coal itself. To some degree it is formed by the burning of lamps, the breathing of men and horses, and the use of explosives, the gaseous products of which almost always contain a certain amount of carbon dioxide. This gas is detected by its action in the flames of lamps which burn feebly or are extinguished in its presence. The effect on human beings is to lower the vitality. It is a common constituent of black-damp, the latter being usually a mixture of carbon dioxide and nitrogen, though there have been cases where the "damp" has been almost pure nitrogen. When coal oxidises it takes up oxygen from the air to form carbon dioxide, and this together with the residual nitrogen from the air, forms the black-damp.

CARBON MONOXIDE (CO)

White-damp, as it is sometimes called in the mines, is a colourless, tasteless, gas, which burns but does not support combustion. It has no smell, and so cannot be detected by this means. It is slightly less dense than air, but the difference in their weights is not sufficiently great for distinct layers of carbon monoxide to be found near the roof. It is an extremely poisonous gas, and very small quantities of it in the air may produce fatal results. As little as ·1 per cent. in the air causes sickness, headache, and loss of muscular power, if breathed for some time. As the quantity increases the effects become more marked, until with about ·4 per cent. to ·5 per cent. in the air a person breathing

it is overcome in a period varying from 5 to 30 minutes. The poisonous effect of this gas is due to its affinity for the hæmoglobin of the red oxygen-carrying corpuscles of the blood, on which it reacts to form carboxyhæmoglobin. Blood so changed appears to be incapable of absorbing and distributing oxygen throughout the system.

Carbon monoxide is formed by burning carbon with a limited supply of oxygen, and is produced in mines as the result of gob fires, burning coal and explosions. It is also occasionally found in the gaseous products from blasting explosives. The deadly effect of the afterdamp of an explosion is mainly due to the presence of this gas.

Tests for the presence of carbon monoxide are of a most unsatisfactory character, and because of this it is a most dangerous contamination. It may be present in fatal quantities and yet give no indication in the flame of the lamp. Tests are usually made by an experienced person noting the effect of a suspected atmosphere on a small warm-blooded animal such as a bird or a mouse. CO acts much more quickly on these animals than on human beings, and in very small percentages of the gas the bird or the mouse begins to show symptoms of poisoning. These successive symptoms are, a decrease of vitality, a loss of control over the legs, and collapse. It is not wise to remain in a suspected atmosphere after the animal has shown the first signs of distress. In a person overcome by this gas the face retains its colour, the lips remain red, and spots about one inch diameter appear on the chest and on the back between the shoulders.

An affected person should be allowed to rest in fresh air but kept warm. Muscular exertion of any kind should be avoided, but if the breathing ceases or is feeble, artificial respiration should be resorted to. The best remedy in carbon monoxide poisoning is the administration of pure oxygen or a 5 per cent. mixture of carbon dioxide in oxygen, it being claimed that the admixture of carbon dioxide stimulates the lung ventilation very considerably.

METHANE (CH_4) AND FIRE-DAMP

This gas is known also as carburetted hydrogen and marsh gas. The fire-damp, or "gas," of coal mines is almost pure methane. Methane is a colourless gas having no taste or smell. It is very light, being little more than half as heavy as air. Its specific gravity is ·56. On this account it is most often found near the roof, in cavities and

breaks, and in places where falls have taken place. It is more often found in rising places than in dipping places.

It is not poisonous in itself, but its presence in the atmosphere causes a deficiency of oxygen which may lead to suffocation in a person breathing such an atmosphere. Methane burns with a pale blue non-luminous flame, and it is this property which renders its detection possible by means of the safety lamp.

A large number of coal seams give off fire-damp to a greater or lesser extent. It is a natural product in the fossilisation of the vegetable matter which forms coal. It is regarded as being occluded in the coal, and sometimes it is held under very great pressure in the pores and fissures. Sometimes it escapes into the surrounding strata, and where the seam is on the dip with a natural outcrop at the surface such a seam is commonly found to contain no gas until a considerable depth is reached.

Generally speaking fire-damp issues gradually from the coal, and the hissing and crackling in a freshly exposed face indicates its presence. It sometimes happens that "blowers" or "outbursts" occur which release large volumes of this gas from the coal or surrounding strata. In the case of those from the strata the gas may continue to be discharged for a long period, the gas having been stored in the joints and in the more porous beds. "Outburst" is the name given to a heavy sudden discharge of short duration, the discharge of the gas being accompanied by the release of large quantities of the small coal by which the gas had been previously absorbed.

The liberation of fire-damp from coal depends almost entirely upon the rate at which fresh faces are exposed. To a slight extent it is affected by variations of atmospheric pressure. Such variations in pressure, nevertheless, sometimes do affect the quantity of gas found in the ventilating circuit to a large degree. This is brought about when fire-damp has accumulated in the goaves or wastes, and in cavities in the surrounding strata; a drop in barometric pressure results in the gassy atmosphere expanding and so coming out into the ventilation circuit. According to the Coal Mines Act 1911 (Sect. 71) "a barometer . . . shall be placed above ground in a conspicuous position near the entrance to the mine"; and the regulations state "Every person on whom responsible duties are imposed with respect to the ventilation underground, and who is required to make a daily report in a book to be kept at the mine for the purpose, shall, immediately

before going into the mine and after coming out of the mine, read the barometer required to be placed near the entrance to the mine . . ." Some colliery managers insist on all firemen reading the barometer and entering the reading in their daily reports. In a gassy mine a fireman should be particularly careful how he handles his lamp when testing for gas after a fall in the barometer.

According to the relative quantity present in the air, methane, on ignition, either burns quietly or explodes. At normal temperature and pressure explosion will take place in mixtures containing from 5·5 per cent. to 15 per cent. methane, and the greatest explosive violence is attained when the mixture contains 9·5 per cent. of the gas. When over 15 per cent. is present in the mixture it will burn more or less rapidly according to the confinement.

The regulations relating to the withdrawal of workmen on account of the presence of inflammable gas are dealt with in Section 67 of the Coal Mines Act. Every fireman and shotfirer should be thoroughly acquainted with these regulations, and the section is here quoted in full.

"WITHDRAWAL OF WORKMEN"

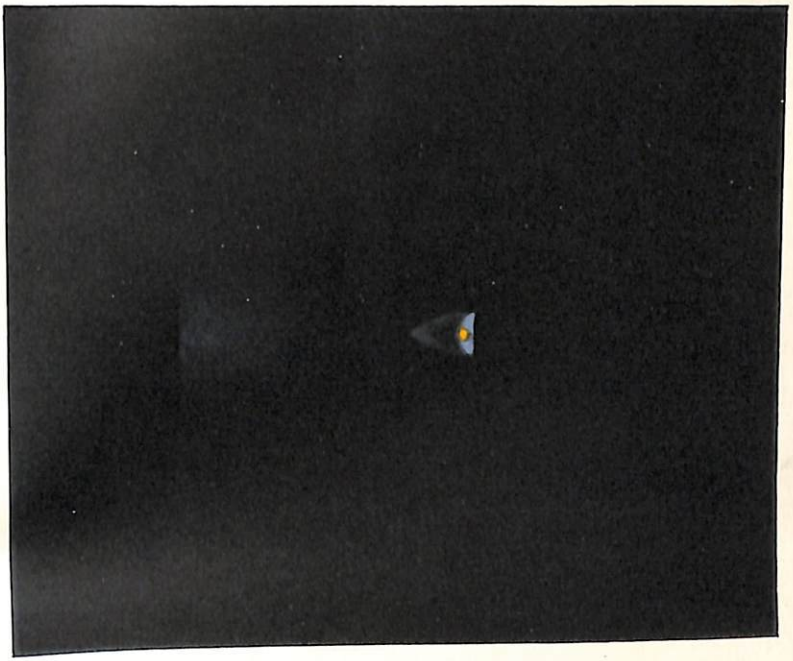
"67.—(1) If at any time it is found by the person for the time being in charge of the mine, or any part thereof, that by reason of the prevalence of inflammable or noxious gases, or of any cause whatever, the mine or any place in the mine is dangerous, every workman shall be withdrawn from the mine or place found dangerous, and a fireman, examiner, or deputy, or other competent person authorised by the Manager or Under-Manager for the purpose shall inspect the mine or place found dangerous, and, if the danger arises from inflammable gas, shall inspect the mine or place with a locked safety lamp, and in every case shall make a full and accurate report of the condition of the mine or place; and a workman shall not, except in so far as is necessary for enquiring into the cause of danger or for the removal thereof, or for exploration, be readmitted into the mine or place found dangerous, until the same is reported by the fireman, examiner, or deputy not to be dangerous.

(2) For the purposes of this section, a place shall be deemed to be dangerous if the percentage of inflammable gas in the general body of the air in that place is found to be two and half

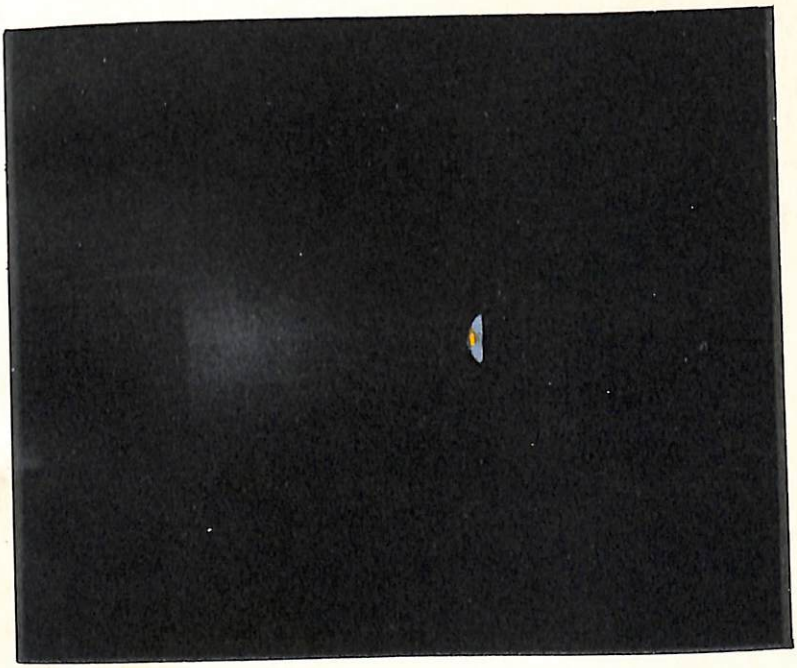
SERIES I.

PRESTWICH PATENT PROTECTOR LAMP

(Spirit, $\frac{1}{4}$-inch Round Wick).



(2) 2·0 per Cent. Firedamp.

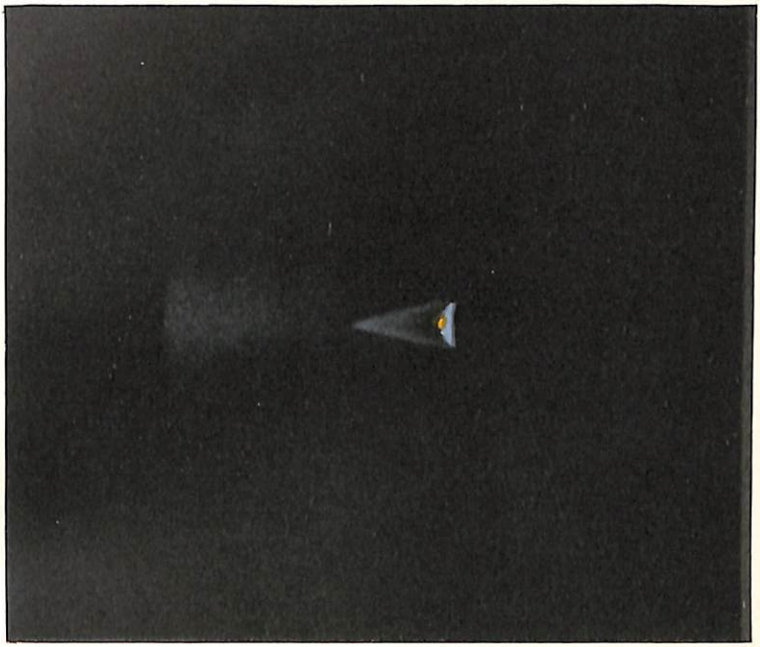


(1) Testing Flame alone.

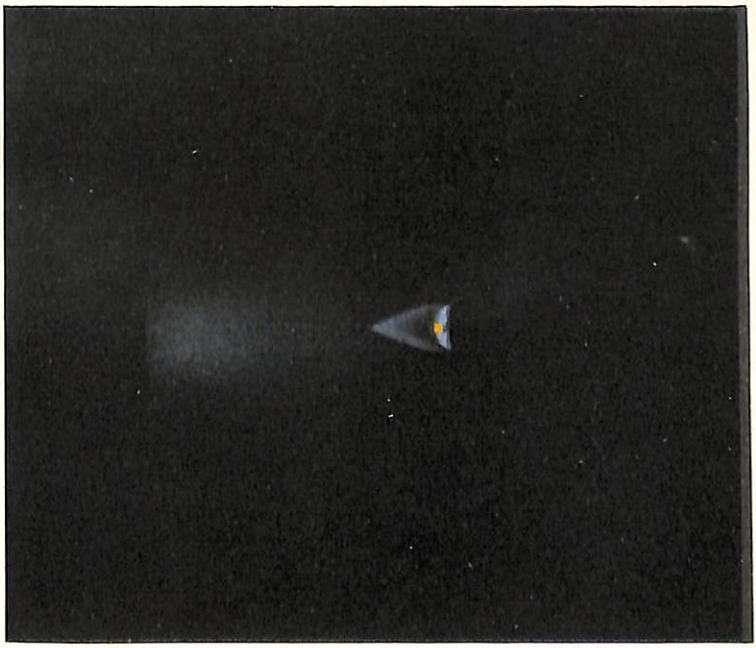
SERIES I. (Contd.).

PRESTWICH PATENT PROTECTOR LAMP

(Spirit, ¼-inch Round Wick).



(4) 3·0 per Cent. Firedamp.

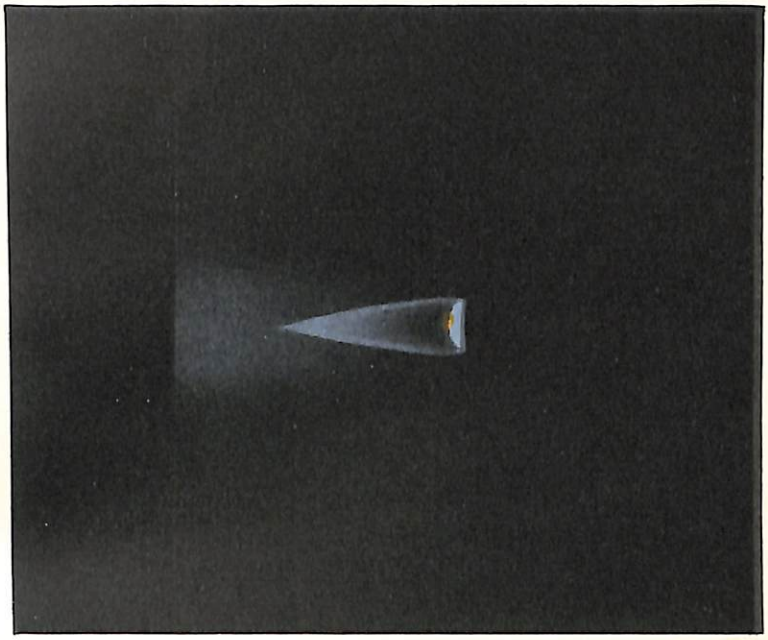


(3) 2·5 per Cent. Firedamp.

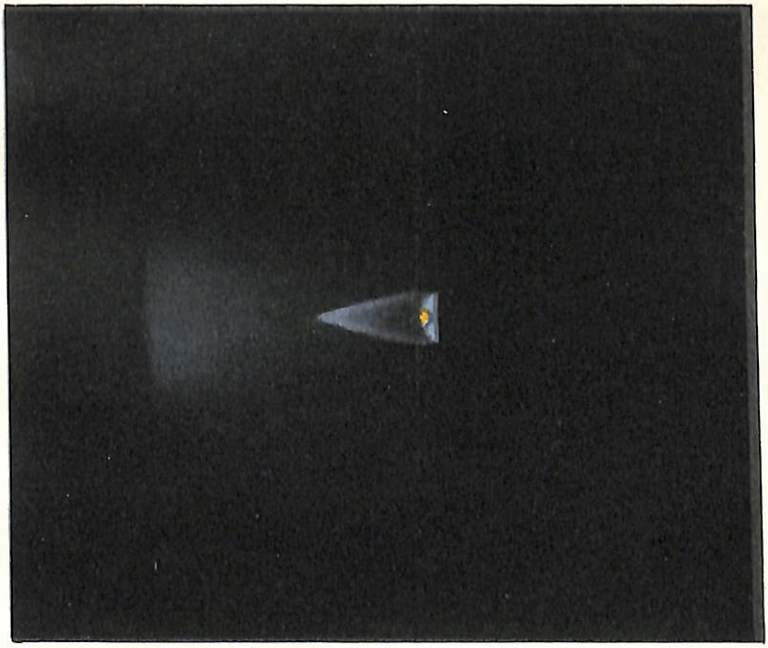
SERIES I (Contd.).

PRESTWICH PATENT PROTECTOR LAMP

(Spirit, $\frac{1}{4}$-inch Round Wick).



(6) 4·0 per Cent. Firedamp.



(5) 3·5 per Cent. Firedamp.

or upwards, or, if situate in a part of a mine worked with naked lights, one and one quarter or upwards.

(3) Every such report shall be recorded in a separate book which shall be kept at the mine for the purpose, and shall be signed by the person who made the inspection.

(4) If a workman discovers the presence of inflammable gas in his working place, he shall immediately withdraw therefrom and inform the fireman, examiner, or deputy."

HOW TO TEST FOR FIRE-DAMP

The ordinary flame safety lamp affords the simplest means of testing for "gas." To make the test the lamp wick should be turned down until only a faint line of blue is seen over the yellow eye, or centre of the flame. The flame will then be about one-tenth of an inch high in the form of a flat arc or dome, according to the form of the wick. This preparation should be done as far as practicable in gas-free air. The lamp should now be raised slowly into the suspected atmosphere. If fire-damp is present a non-luminous flame "cap" of a paler colour than the lamp flame will appear on top of the latter. A 1 per cent. mixture of fire-damp with air is perceptible in this way, but a definite cap is not formed on the flame until 2 per cent. of the gas is present. With increases in the percentage of inflammable gas the cap becomes longer and more distinct. At 2 per cent. the cap is about a $\frac{1}{4}$ inch long; at $2\frac{1}{2}$ per cent. it is about $\frac{3}{8}$ inch long; at 3 per cent. about $\frac{5}{8}$ inch; at 4 per cent. about $1\frac{1}{4}$ inches; and above 4 per cent. the cap extends into the upper part of the lamp chimney. The plates between pages 16 and 17 show gas caps up to 4 per cent. of fire-damp as published by the Mines Department.

Certain kinds of oil produce a faint but perceptible cap on the reduced flame of a safety lamp. As this fuel or oil cap might be mistaken for a gas cap the observer should familiarise himself with the appearance of the reduced flame of his lamp in pure air.

When a cap forms on the flame the lamp should be gently moved to clear air before readjusting the wick to normal height. When a lamp fills with burning gas it is in a very dangerous state. It should then be gently removed to a place of safety, or, if this cannot be conveniently done, it should be carefully smothered. On no account should the lamp be jerked or rapidly moved, for such action is likely to ignite fire-damp outside the lamp.

SULPHURETTED HYDROGEN (H_2S)

This is a colourless gas with a sickly sweetish taste and an extremely offensive odour. On account of its smell, that of rotten eggs, it is called "stink damp" by the miner. It has a specific gravity of 1·18, so that volume for volume it is slightly heavier than air. It burns with a pale blue flame and is moderately soluble in water. It is a very poisonous gas, and when present, even in small quantities, it produces irritation of the throat and eyes, sickness and insensibility. 1 per cent. will cause death in a few minutes.

It is usually present in mine air where there is an underground fire, its presence being due to heating coal containing iron pyrites. It may be liberated from the coal along with fire-damp, and it may be given off from stagnant water which has percolated into the workings. Fortunately it is rarely found in dangerous quantities in mines and is readily detected by its smell, one part in 100,000 of air being noticeable by this means.

AFTER-DAMP

This is a dangerous and unbreathable mixture of gases resulting from an explosion of fire-damp and air, coal-dust and air, or a combination with air of fire-damp and coal dust. The resultant gases from a mine explosion depend upon the quantity of methane and the nature of the coal dust present before the explosion takes place. The following gases might be expected from an analysis of after-damp: Carbon dioxide; carbon monoxide; nitrogen; water vapour; and unconsumed oxygen, together with traces of unburnt methane and sulphur compounds. The most dangerous component is undoubtedly carbon monoxide, and it is estimated that about 80 per cent. of the deaths caused by mine explosions are attributable to CO poisoning. It is thus necessary when carrying out rescue work or exploring the workings after an explosion, that every precaution should be taken to guard against an atmosphere containing this gas. The plan of action after an explosion is usually arranged by some competent person, such as the colliery manager or a mines inspector, who organises the rescue and exploring parties and takes the necessary steps on the surface with regard to the ventilating plant and the setting aright of the winding gear, if it has been damaged or deranged; but the underground fireman is frequently called upon by reason of

his intimate knowledge of roads and air-ways to carry out an important part of the work.

Much can be written, and has been written, on the procedure to be adopted in carrying out rescue operations, but it does not fall within the scope of this booklet to deal with such matters in detail. A few recommendations to firemen and others forming the exploring party, however, may not be amiss.

The party should have electric as well as flame safety lamps. As tools, brattice cloth and some timber for temporary repair work are also likely to be carried, it is not desirable to overburden everyone by carrying two lamps; probably the best arrangement would be for every man to carry a flame lamp and two men to carry also an electric lamp. The leader should carry one of each kind. The flame safety lamp is necessary to show the presence of fire-damp, if any, but on account of the difficulty of keeping these lamps burning, when passing over debris or when crawling through narrow passages, electric lamps should be available for lighting purposes.

A canary, or a mouse, should be carried for the detection of carbon monoxide. As soon as the presence of this gas is indicated the party should retire to a place where the air is free from gas. The intake air should be followed, and no one should venture ahead of the air-current unless fitted with a breathing apparatus. The party should proceed cautiously, and the roof, sides, and supports should be examined during the journey in-bye. If there is any likelihood of a fall the place should be made secure before proceeding.

When the atmosphere is clear the route taken by the party should be clearly marked by the leader at all road junctions, by means of arrow-marks in chalk. When the atmosphere is thick with smoke a life-line should be led in from fresh air, and no member of the party should move out of reach of that line. If such a course is not practicable every road branching from the route should be fenced across the opening.

MOISTURE IN MINE AIR

There is always a certain amount of moisture present in the atmosphere, but the quantity varies greatly from place to place, and from time to time in each place. Air which contains much moisture or water vapour is said to be humid, and the amount of such moisture is referred to as the humidity of the air. When air at any temperature

contains its maximum amount it is said to be saturated at that temperature, and the relative humidity is 100 per cent. When moist air is cooled there is a point at which it deposits the vapour as water; this is called the dew-point.

High relative humidity adversely affects not only the health of the workers, but also the economic working of the mines. It causes very slow evaporation of perspiration, and the workmen become very uncomfortable and easily tired. It is most important, therefore, that the moisture content of the air should be kept as low as possible.

The humidity of the air is measured by means of a hygrometer, and the Coal Mines Act stipulates that a hygrometer shall be placed below ground in a conspicuous position near a shaft or outlet, both in the main intake airway and in the main return airway; General Regulations state that each hygrometer placed below ground in pursuance of the Act shall be read by "a responsible official" of the mine once every week-day if in the main intake airway, and once every week if in the main return airway. This regulation applies only to mines in which coal is worked.

The most common type of hygrometer is the wet-and-dry-bulb thermometer. The dry-bulb records the air temperature, and the wet-bulb gives a temperature which varies according to the humidity of the atmosphere. When the air is fairly dry the wet-bulb reading is relatively low on account of evaporation of the water on the bulb. As the humidity approaches saturation point, so the wet-bulb reading approaches the dry-bulb reading. From the table on page 21, the percentage saturation can be obtained at dry-bulb temperatures ranging from 30°F. to 100° F., with differences of dry-and-wet-bulb readings of from 0°F. to 12°F.

To give some idea of the actual weight of water contained in a saturated atmosphere,

1,000 cubic feet of air at		32°F.	contains	·31	lb. of water
,,	,,	40°F.	,,	·41	,,
,,	,,	60°F.	,,	·84	,,
,,	,,	80°F.	,,	1·57	,,

It is thus seen that the higher the temperature the greater is the amount of water the air is capable of holding.

Consider the case of a mine in which the air entering the downcast shaft gives a dry-bulb reading of 40°F. and wet-bulb reading of

DIFFERENCE BETWEEN DRY-BULB AND WET-BULB READINGS IN DEGREES FAHRENHEIT

DRY-BULB READING	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	DRY-BULB READING
32°	100	87	76	65	56	48	41	35	30	27	23	19	16	32°
36°	100	91	82	74	66	59	53	47	42	38	34	30	27	36°
40°	100	92	84	76	70	63	58	52	47	43	38	34	31	40°
44°	100	92	84	78	72	65	60	55	50	46	41	38	34	44°
48°	100	92	85	79	73	67	62	57	52	48	44	40	36	48°
52°	100	93	86	80	74	69	63	59	54	50	46	43	39	52°
56°	100	93	87	81	75	70	65	60	56	52	48	45	41	56°
60°	100	93	88	82	76	71	66	62	58	54	50	46	43	60°
64°	100	94	88	82	77	72	68	63	59	55	52	48	45	64°
68°	100	94	88	83	78	73	69	65	60	56	53	50	46	68°
70°	100	94	89	83	78	74	69	65	61	57	54	50	47	70°
75°	100	94	89	84	79	74	70	66	62	59	55	52	49	75°
80°	100	95	90	85	80	76	72	67	64	60	57	53	50	80°
90°	100	95	90	85	81	77	73	69	65	62	59	56	53	90°
100°	100	95	90	86	82	78	74	70	67	64	61	58	55	100°

35°F. and the air leaving the upcast shaft gives a dry-bulb reading of 60°F. and wet-bulb of 58°F. From the table it is seen that the relative humidity of the in-take air is 63 per cent., therefore the weight of water per 1,000 cubic feet is

$$\frac{63}{100} \times \cdot 41 = \cdot 26 \text{ lb.}$$

The return air is 88 per cent. saturated.

$\therefore$ 1,000 cubic feet contains $\frac{88}{100} \times \cdot 84 = \cdot 74$ lb.

$\therefore$ Each 1,000 cubic feet of air leaving the pit has taken up $\cdot 74$ lb. $- \cdot 26 = \cdot 48$ lb. of water.

Suppose 100,000 cubic feet of air per minute is being circulated, then 48 lb. is taken out of the pit each minute. In 24 hours this comes to approximately 7,000 gallons.

Air may enter a downcast shaft at a comparatively low temperature, but by the time it has circulated through the workings and returned to the upcast shaft, the temperature may be uncomfortably high through heat being taken from the strata. Although not strictly accurate for any one place, it is taken as an average throughout the British coalfields that at 50 feet of depth the temperature of the rocks is constant at 52°F., and for every 60 feet of further depth the strata temperature rises 1°F. Thus at a depth of 1,200 feet (200 fathoms) the rock temperature will be about 71°F.

To assist in keeping cool when working, the miner divests himself of most of his clothing. Nature, too, plays a part in keeping the worker cool. Heat causes the formation of perspiration which is evaporated if the atmospheric conditions are suitable, and in evaporating it has a cooling effect on the body. The atmospheric conditions necessary for good evaporation are air movement and low humidity.

Dr. T. David Jones writing on "Hygrometry in Mines" stated, with reference to a district he knew well in a particular colliery, "The temperature in this district was 86°F. dry-bulb with a relative humidity of from 92 to 96 per cent. Such a dry-bulb temperature is low as compared with some of the air temperatures obtained in this and other coalfields. The men in this district could produce only 40 per cent. of the output produced by the same men in another district

where the relative humidity was about 70 per cent. at the same dry-bulb temperature, and other conditions were alike. . . . taking the efficiency of the human body at 25 per cent., in the case cited we have only 40 per cent. of this, namely, 10 per cent. This low efficiency is undoubtedly caused entirely by the high relative humidity of the air, which is detrimental to the efficient working of the human body."

The best way to keep the moisture content of the air as low as possible is to maintain good ventilation, as stagnant or slow-moving air soon rises to the strata temperature and soon also becomes saturated if the strata contain water. So far as the fireman is concerned, he can usually improve the ventilation of his own district by preventing leakage of air through stoppings, gobs, etc., for a surprisingly large percentage of air is lost in this way, even in well-organised mines.

Chapter III

COAL DUST AND ITS TREATMENT

That coal dust can add very materially to the extent of a mine explosion has been amply demonstrated in many of the large and catastrophic explosions which have taken place, both in this country and abroad. It is sometimes stated that coal dust alone will not cause an explosion and that the presence of gas is an essential to the initiation. Although the likelihood of an explosion by coal dust without the presence of some gas is small, it has, nevertheless, been effectively shown at the Government experimental stations that when certain conditions obtain coal dust alone can produce an explosion. It should be understood, of course, that neither gas nor coal dust will explode without the assistance of some such agency as a blown-out shot, an electric spark, the flame of a lamp, or spontaneous combustion in the coal itself. The most common initial cause of colliery disasters is a small fire-damp explosion, but the propagation of the explosion throughout the workings may be, in the main, caused by coal dust. These facts not only make the treatment of coal dust advisable, but have led to its being made compulsory.

Coal dust is produced in the mine in various ways. Coal-cutting machines throw clouds of dust into the air-current. Ordinary pick work produces a certain amount. In handling coal hutches from inbye, it frequently happens that some coal is shaken out of the hutch to be crushed to fine dust in the haulage road. The jolting and bumping of the hutches alone is also productive of a certain amount of dust. In the older collieries where the pit-head screening arrangements are close to the shaft mouth, vast quantities of fine dust are carried from the tipplers and screening tables down the downcast shaft. The provisions of the Coal Mines Act guard against this latter cause of coal dust in the newer mines, for in the case of pits sunk since 1911 the screens must be situated at least 80 yards from the downcast shaft.

The light dust is carried in the air-current and deposited on roof timbers and any ledges and projections on the sides, as well as on the pavement. The dust deposited on the pavement is often rendered harmless by reason of being mixed with fine shale or rock produced in a manner similar to some coal dust. Shale and rock fall from the

roof and sides or are shaken out of hutches carrying debris to the surface. This is crushed by passing traffic, but, as a rule, the particles are not light enough to be carried up to the roof timbers or projections on the sides. This rock dust, however, adds its quota to the rendering innocuous of coal dust on the pavement.

In addition to the provision regarding screening plant, the Coal Mines Act makes it necessary that tubs shall be so constructed and maintained as to prevent, so far as practicable, coal dust escaping through the sides, ends, and floor of the tubs. The floor of every travelling road must be cleared of coal dust at regular intervals so as to prevent coal dust from accumulating. The interval must be fixed by agreement between the Manager and the workmen or their representatives, or if they cannot reach an agreement, by the Inspector of the Division. Roads must be examined daily, and a report made on their condition as to coal dust (specimen report in Appendix III, page 79).

Systematic steps must be taken to prevent explosions of coal dust occurring or being carried along the roads. The amended regulations up to and including the order issued on the 20th November, 1924, for all mines in which coal other than anthracite is worked, state that the floor, roof, and sides, of all accessible roads of any description extending from the shaft or out-let to within 10 yards of the coal face, shall be treated, either by incombustible dust to ensure that dust on the floor, roof, and sides, respectively, shall contain not more than 50 per cent. of combustible matter, or by water, so that the dust is always combined with 30 per cent. by weight of water in intimate mixture. The percentage of incombustible dust required may be reduced by an amount equivalent to the percentage of water present in the mixture.

The use of water, even when satisfying the conditions of the Mines Act, is only in few instances to be preferred as a means of allaying the coal dust danger. At first sight it may appear to be a simpler method than using an inert dust, but mere sprinkling of water from a bucket or spraying, unless the water is reduced by the spraying jet to a very fine state of division, will not render coal dust harmless. Pools of water on the floor, apart from the discomfort they cause in travelling roads, are not a sure safeguard against a coal dust explosion, even when the roof and sides are also treated. Fine dust will float on the surface of pools and may be wafted into the air when an explosion occurs. Rocks commonly found associated with coal,

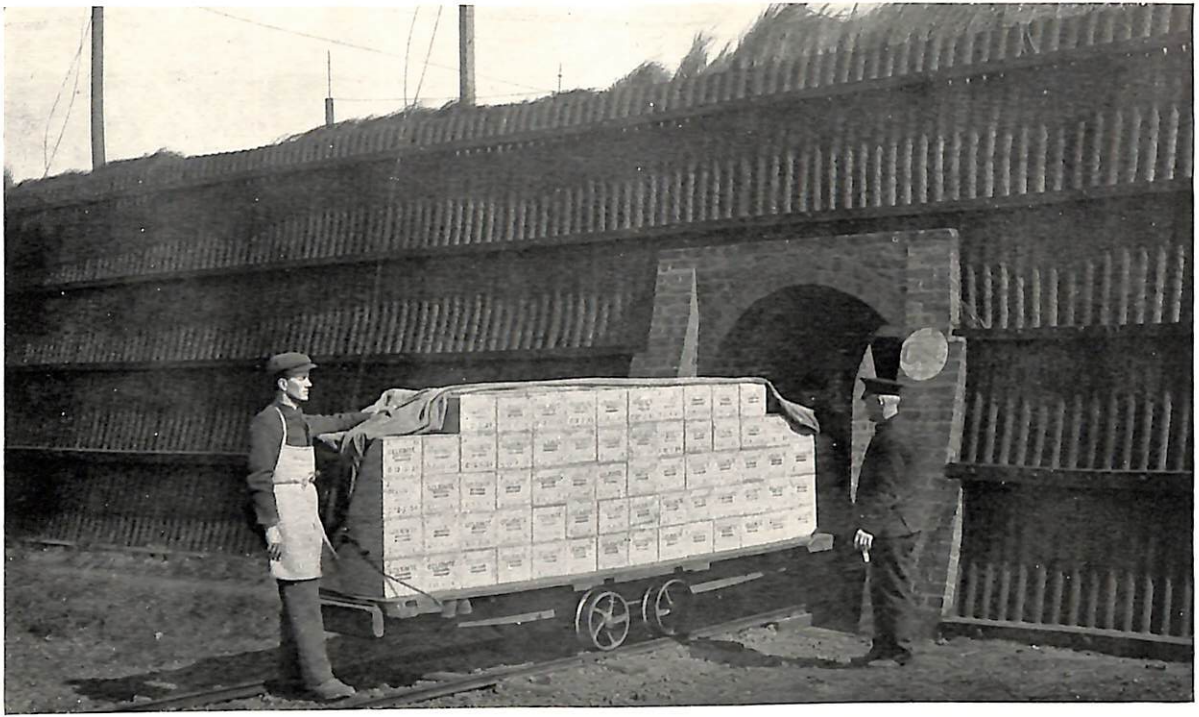
such as blaes and shales of a limey nature, are acted upon by water, and water treatment is apt to produce falls from the roof and sides. Furthermore, mine air is rendered unnecessarily humid by the application of water, and, as has been mentioned earlier in the book, air with high humidity has a deleterious effect on workmen. A further disadvantage of watering is that it must be repeated very frequently to make allowance for evaporation.

There are, of course, some cases where water is successfully applied. Perhaps the most suitable way is by means of pipe lines from the surface, or from a shaft lodgment high enough to give a sufficient head for distribution. The pipe lines are led into the roads, and have short branch pieces at intervals of from 30 to 40 yards fitted with spraying nozzles turned in the direction of the air current.

The incombustible dust used must contain not less than 50 per cent. of fine material, capable when dry, of passing a sieve with 200 meshes to the linear inch. If, however, a larger proportion of incombustible dust is used than is required by the regulation, the percentage of fine material may be reduced proportionately, but must not fall below 25. Several varieties of incombustible dust were tested by the Explosions in Mines Committee, who state "that the fineness of an incombustible dust rather than its chemical composition affords a measure of its probable effectiveness in preventing the ignition of coal dust with which it may be mixed."

Regarding the kind of dust which should be used, the regulations state, "No dust shall be used . . . of a kind which may be prohibited by the Secretary of State on the ground that it would be injurious to the health of persons working in the mine . . . " It has been shown that shale dust may be used quite safely, and that powdered clay or chalk (free from flint or grit) is also practically harmless. Dust from stone such as ganister or sandstone may cause serious risk of phthisis, and dusts of a gritty nature, such as powdered slag, clinker, or flue dust, may produce considerable irritation to the eyes or throat. Limestone dust, provided that it does not contain more than a trace of free sulphide, is suitable for stone-dusting mine roads. Dr. J. S. Haldane has shown that the dust of argillaceous shale such as is found interstratified in the coal measures in most mines in the United Kingdom, although it contains silica, is not in the least likely to prove a danger to health.

The two main methods of distributing stone dust are by hand and



Ardeer Factory.
Finished explosives going into magazine.

To face page 26

by mechanical means. In hand distribution the inert dust is scattered from bags or tubs over the surfaces of the roadway. It is almost unnecessary advice, for the comfort of the workman on the job, to say that the dust should be thrown in the direction of travel of the air-current. This method has probably the widest application, and though perhaps not the most economical there is much to be said in its favour. It can be carried on during the working shifts, as there is no great quantity of dust thrown into the air-current. Coal dust concealed above crowns and behind legs, and in all kinds of crevices, is effectively dealt with by this method.

Mechanical distribution is in general carried out by means of compressed air jets, or by some self-contained apparatus on the lines of the "Oldham" stone dusting tub. Both of these methods cause large quantities of dust to be thrown into the air-current, so that the work must be carried out at week-ends or at other times when the roads are clear of men. In using compressed air some kind of feed hopper is affixed above the jet. Either a long length of hose is required, or a shorter length and suitable couplings in the supply line at intervals equal to the length of the hose. In the stone-dusting tub the dust is thrown into the atmosphere by means of a fan driven from the axle shaft through a chain drive and multiple gearing. When the tub is stationary the fan is driven by means of a hand lever.

The following extract from the Safety in Mines Research Board Paper No. 2 is of interest:

> "Some mining engineers contend that stone-dusting by hand is impracticable where there are great lengths of roadway to be dealt with, also that stone dust can be distributed more evenly by mechanical means than by hand. There is little evidence to support these views. When stone dust is applied effectively by hand it displaces the coal dust from the ledges and other horizontal surfaces of the walls and timbers, and covers these surfaces with stone dust as deep as its angle of repose will allow, so that coal dust subsequently deposited will tend to slide off the stone dust surface on to the floor of the roadway, where it is more easily dealt with."

Chapter IV

MEASUREMENT OF AIR IN AN AIR-CURRENT

In every mine the quantity of air in the air-current must be measured at the following points at least once in every month, and entered in a book kept for the purpose.

(*a*) In the main intake airway of every seam as near as practicable to the downcast shaft.

(*b*) In every split as near as practicable to the point at which the split commences.

(*c*) In each ventilating district at or as near as practicable to a point 100 yards back from the first working place at the working face which the air enters.

As previously stated, a fireman must be capable of measuring the quantity of air in an air-current. The quantity of air passing in an airway in unit time is the product of the velocity in that time and the area. To make the measurement it is necessary to know the speed of the air and the cross-sectional area of the airway.

The velocity at which air is travelling may be measured in naked light mines by means of a smoke cloud, but it is more common practice to use an anemometer of the windmill type, of which there are many makes on the market.

To measure the speed of the air by means of a smoke cloud requires two men, and should be carried out on a length of the airway, say 50 to 100 feet, where the cross-sectional area is as nearly uniform as possible. The smoke cloud is produced by burning a piece of fuse or some similar substance capable of giving off a fair cloud in a short time. The man on the intake side of the measured length of roadway lights the smoke producer, notifies the man at the other end the moment smoke is evolved, and the latter notes the time it takes for the cloud to reach him. The test should be repeated two or three times and the average taken.

Say the length chosen is 80 feet and the time of travel is 25 seconds then to find the velocity:

In 25 seconds the air travels		80 feet
In 1 second	,,	$\frac{80}{25}$ feet
In 60 seconds	,,	$\frac{80 \times 60}{25}$ feet, *i.e.* 192 feet.

If the average cross-sectional area is 60 square feet then the quantity of air passing is:

$$192 \times 60 = 11{,}520 \text{ cubic feet per minute.}$$

Fig. 1 shows a windmill type anemometer such as is commonly used in collieries. It consists of a number of small thin vanes fixed radially on a small shaft, which is geared on to a recording device fitted with an indicator. The indicator has a main dial which reads in feet, and, as a rule, has in addition two or three smaller dials on its face reading in hundreds, thousands, and ten thousands of feet.

FIG. 1
(As supplied by John Davis & Son (Derby) Ltd.)

Most instruments have a small lever or clutch by means of which the recording device can be thrown into or out of gear with the vane shaft. To make a measurement with an anemometer, the instrument is held in the air-current with the plane of the circle in which the vanes are set at right angles to the direction of travel of the air. The vanes are allowed to revolve for a moment with the recording device out of gear. The reading is taken on the indicator and at the commencement of a fixed period, usually a minute, of the test, the recorder is set in gear. At the end of the minute run the recorder is stopped, and the reading taken. The difference between the two

readings gives the velocity of the air in feet per minute. If the period of the test is two minutes, then, of course, the difference between the two readings requires to be divided by two, and if the period is half-a-minute the difference should be multiplied by two, and so on. To obtain a true estimate of the speed of the air, two or three readings should be taken in each of several points in the cross-section of the road. For example the points indicated in the sketch would be suitable for a roadway of that size. The mean reading at each point should be obtained and the mean of the five points taken. Another method is to take two or three readings, moving the anemometer about in a plane at right angles to the direction of the air current.

There is little difficulty in finding the cross-sectional area of what are the most common forms of airways, the square and the rectangle. The area is equal to the width multiplied by the height.

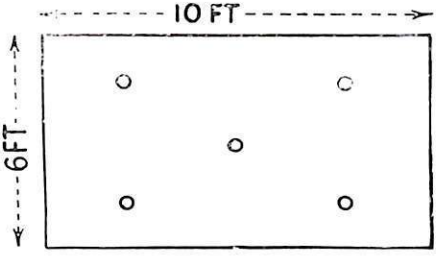


FIG. 2

Examples: Airway 10 ft. × 10 ft. Area = 100 square feet
,, 10 ft. × 6 ft. ,, = 60 ,,
,, $8\frac{1}{2}$ ft. × $5\frac{1}{2}$ ft. ,, = $46\frac{3}{4}$,,

Other forms are the trapezoidal, circular and arched airways.

A trapezium is a four-sided figure in which two sides are parallel. To find the area of this figure, add together the widths of the parallel sides, divide by two and multiply the result by the height.

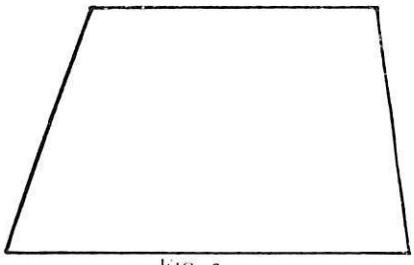


FIG. 3

Example: A roadway is $7\frac{1}{2}$ feet wide at the roof, and $10\frac{1}{2}$ feet wide at the floor, and the height is 6 feet 6 inches. To find the cross-sectional area:

$$\text{Average width} = \frac{7\frac{1}{2} + 10\frac{1}{2}}{2} = 9 \text{ feet}$$

$$\text{Area} = 9 \times 6\frac{1}{2} = 58\frac{1}{2} \text{ square feet}$$

A circle is a line lying in a plane such that all points in the line are equidistant from a certain fixed point called the centre of the circle. The fixed distance is called the radius, and the diameter is twice the radius. The line forming the circle is called the circumference.

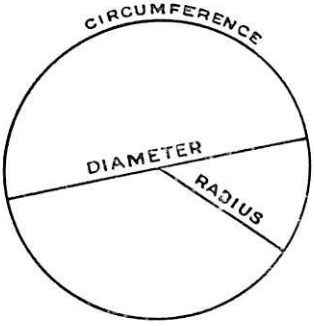


FIG. 4

The circumference of a circle is for many practical purposes taken as $3\frac{1}{7}$, or, more accurately, 3·1416 times the diameter. This ratio is denoted by the Greek letter π

$$\text{C (circumference)} = \pi \times \text{d (diameter)}$$
$$= 2\pi \times \text{r (radius)}$$

The area of a circle is 3.1416 multiplied by the square of the radius

$$\textit{i.e.}\ \text{Area} = \pi r^2 = \frac{\pi}{4} d^2$$

Example: Find the area of a circular shaft having a diameter of 20 feet.

$$\text{Area} = \frac{\pi}{4} d^2$$
$$= \cdot 7854 \times 20 \times 20$$
$$= 314 \text{ square feet}$$

The result is given to the nearest square foot, which is a close enough approximation for most airway calculations.

In the case of an arched roadway in which the top portion is semi-circular resting on vertical sides, the area is found by adding

together the area of the rectangle ABCD and the area of the semi-circle.

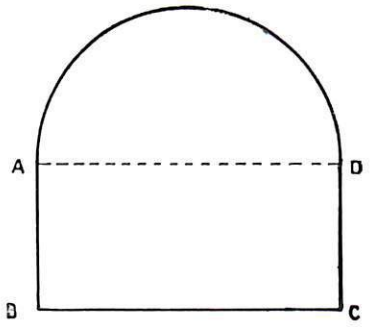


FIG. 5

Example: If the dimensions of such an airway were 12 feet wide and 4 feet in the vertical portions, the area would be found as follows:

Area of rectangle $= 12 \times 4 = 48$ square feet

Area of semicircle $= \frac{\pi r^2}{2}$

r in this case is half of 12 $= 6$ feet

Area then $= \frac{3{\cdot}1416 \times 6 \times 6}{2} = 57$ square feet

Area of the airway $= 48 + 57 = 105$ square feet

Chapter V

VENTILATING PRACTICE

To comply with the Coal Mines Act an adequate amount of ventilation must be constantly produced in every mine to dilute and render harmless inflammable and noxious gases. Intake airways up to within 100 yards of the first working place at the working face which the air enters must be normally kept free from inflammable gas. To fulfil these conditions the mine air must contain not less than 19 per cent. of oxygen and not more than $1\frac{1}{4}$ per cent. of carbon dioxide, and the intake airway is not considered to be free from inflammable gas if the average percentage found in six samples of air taken by an inspector at intervals of not less than a fortnight exceeds one quarter.

In the case of mines liable to spontaneous combustion of the coal, exemption from compliance with these regulations may be granted under certain conditions.

The actual quantity of air to be supplied per person is not laid down. A man at rest breathes about two gallons of air per minute, but when working he may require up to ten times that amount. Not all the air entering a mine, of course, reaches the working face, in fact a very liberal excess over the requirements for the men should be circulated. 100 to 200 cubic feet of air per man per minute and 500 cubic feet per animal is generally reckoned to provide ample ventilation, but since much depends on the mode of distribution, distances of working faces from the shaft, and the rate at which gas is given off from the coal, it is quite impossible to lay down a hard and fast rule on the basis of the number of men and animals underground.

In the shaft and in the main roads near the pit bottom air may be travelling at 10 to 20 feet per second, but such a velocity would be distinctly unhealthy for perspiring men. At 3 feet per second air is in pleasant movement, and a speed of 2 feet to 3 feet per second provides, as a general rule, adequate and satisfactory ventilation. At 4 feet per second a candle flame flickers inconveniently, and at 7 feet per second an oil cap lamp is kept alight with difficulty.

Apart from the objects of diluting and removing gas, and of providing fresh air for men and horses, a brisk current of air helps in deep mines to cool the working places, and to render the atmospheric

conditions suitable for the conduct of work. A plentiful supply of cold air reduces the chance of spontaneous combustion in coal likely to be affected in this way. In addition, the air current may be responsible for carrying out of the mine large quantities of coal dust.

The production of the main ventilating current in a mine does not come within the duties of a fireman, and need only be mentioned here.

Mine ventilation may be produced in various ways, *e.g.* natural means, furnace, steam jets, and fans. Natural ventilation is not a safe means of producing a current and should not be relied upon where gas is likely to be found. Furnace ventilation is restricted to mines employing no more than 30 men, and then only when the upcast shaft contains no inflammable material. Steam jets are suitable only for very small workings. In the vast majority of mines in this country ventilation is produced by means of a mechanically driven fan.

If there is a plentiful supply of air coming into a fireman's district the distribution to the working places is not a difficult matter. There may be a multiplicity of roads in the section, but by the simple process of shutting off the roads through which the air is not to pass, the current may be directed through the desired route.

The intake and return airways to and from any section are usually parallel to each other, and not very far apart. In driving these airways, cross-cuts, or "throughers," are usually driven at frequent intervals for convenience of ventilation and haulage. In the course of development the cross-cuts fall into disuse, and stoppings must be erected to prevent short circuiting of the air from the intake to the return. The Coal Mines Act states that in coal mines all such stoppings must either be constructed of tight stone, dirt, sand, or rubbish packing, at least 5 yards thick, or if the side nearest the intake is faced with a wall of masonry not less than 9 inches thick, and the face of masonry covered with a coating of mortar so as to prevent air leakage, 3 yards thick. The mines in South Staffordshire liable to spontaneous combustion in the unworked coal are exempted from this regulation.

The shutting off of air from any road is effected in various ways, according to the purposes for which the road is used. When the road to be closed to air is not used for any purpose, a tight dirt pack makes a suitable stopping. When the road is used for travelling or haulage, then wooden or iron trap-doors or canvas screens are erected. Properly constructed trapdoors make efficient stoppings, but they are

inconvenient in haulage roads, especially when they are close to the working places. On account of being easily put out of place by roof squeeze they are somewhat costly in upkeep.

Canvas screens are readily put up and do not hinder the haulage, though they are liable to drag coal from the tops of the hutches. This coal should be removed regularly, otherwise it will be pounded to dust by the passing traffic, and will be, in consequence, a potential danger.

Trap-doors may be required in headings and levels, but canvas screens are, as a rule, sufficient for branch roads.

Fig. 6 shows the ventilating arrangements in a longwall district using trap-doors, screens, and dirt packs.

During development work, single roads are often driven for such a distance, or the distance between cross-cuts (where double roads

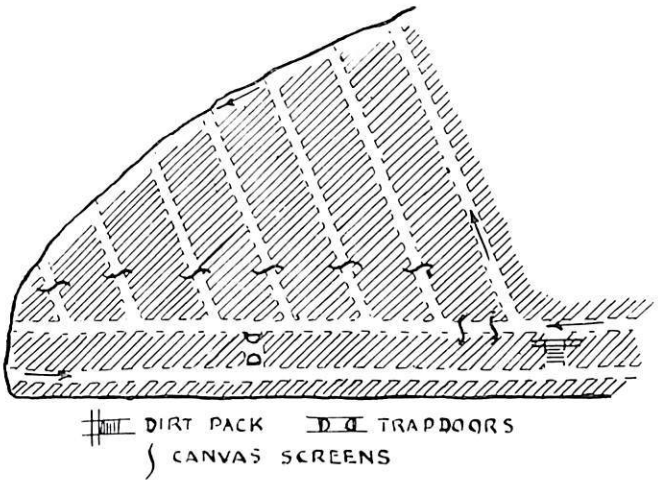


FIG. 6

are driven) may be so great that some means of ventilating the face is necessary. To ventilate such places the air is conducted to the face by bratticing, or by air pipes. Brattice may be of cloth, wooden boards, or brickwork, according to the length of time it has to stand.

Fig. 7 shows a method of ventilating two roads where the cross-cuts go off about every 250 feet. Props are put up every 10 feet or so, and to them light brattice deals are nailed close to the roof; from

the deals the brattice cloth, a coarse-woven canvas, is hung. At the points A A the screen is in the form of a flap to allow the passage of traffic. The brattice is extended with the advance of the face until the next cross-cut is made, when a stopping is built in the first cross-cut. The props, brattice deals, and cloth, can be used several times.

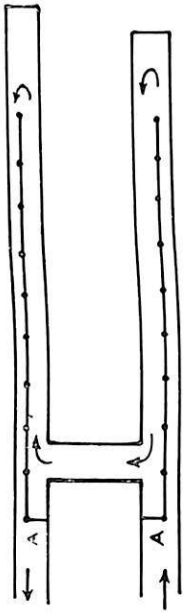


FIG. 7

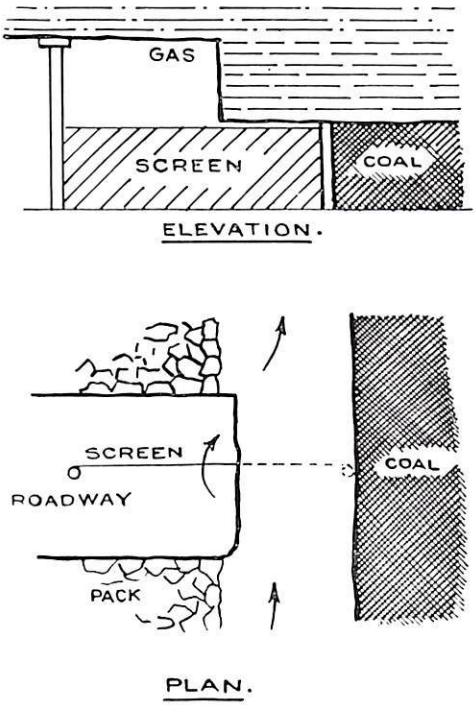


FIG. 8

When a more permanent partition of a roadway is desired, such, for instance, as might be necessary in a long stone drift, it is built of brickwork, or of deals faced with cloth. Where bricks are used it is advisable to have a layer of wood in the bricks to take any crush which may come on.

Air pipes either of wood, sheet iron, or canvas, are commonly used in conjunction with an auxiliary fan. This arrangement is specially suitable in a district where air is sluggish and needs boosting.

When fire-damp accumulates in roof cavities in an airway it can be removed by putting up a canvas screen in the form of a hurdle. The air mounts this, enters the cavity and carries the gas out with it on the other side of the screen. In gassy mines fire-damp is often found in the face of the brushing clear of the air current. Such accumulations can be expeditiously removed by erecting a hurdle as shown in Fig. 8. The air travelling along the coal face encounters the screen and is forced out into the roadway; it flows over the hurdle and sweeps the gas out into the current to be carried into the return and so out to the atmosphere.

It is a contravention of the Coal Mines Act to brush or waft out gas.

Chapter VI

SAFETY LAMPS

As a result of the many serious accidents arising from the ignition and explosion of gas in mines, it was but the natural trend in the advancement of science that consideration should have been given to the question of supplying a lamp which, whilst giving the miner the necessary illumination to pursue his work, would, at the same time, safeguard him against ignitions of inflammable gas.

The history of the invention and improvement of safety lamps is very interesting, but in this short study of the subject it will only be touched upon.

FLAME SAFETY LAMPS

Dr. Clanny invented the first safety lamp in 1813. This lamp consisted of a burner base to which was fixed a cylindrical iron chimney fitted with a glass window, and having a conical extension at the top. The air for combustion was fed in by means of a bellows, so it was necessary to have a boy constantly in attendance on the lamp.

Two years later Sir Humphry Davy, who was a friend of Dr. Clanny and had seen the latter's bellows lamp in use, produced a lamp fitted with a gauze cylinder in place of the iron cylinder of the Clanny lamp. The gauze attachment was the forerunner of the safety principle embodied in all modern flame safety lamps.

The principle on which the safety feature is founded is that while air can pass freely through the meshes of the gauze from the outside,

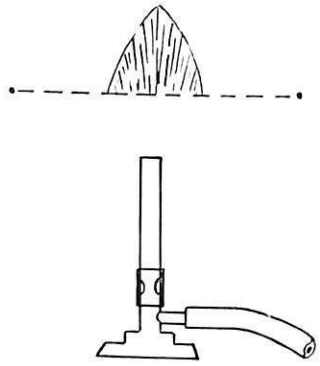


FIG. 9

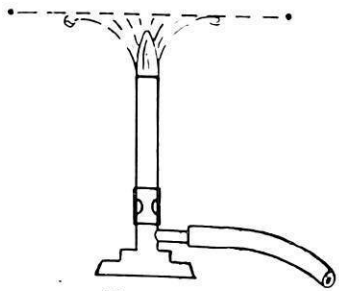


FIG. 10

the flame produced in the inside is so cooled by contact with the wires that it cannot, within reasonable limits of time and heat produced, pass to the outside atmosphere. This is readily demonstrated as shown in Figs. 9 and 10 by placing an ordinary Bunsen burner below a sheet of wire gauze and turning on the cock. If a light is applied above the gauze, the gas will burn only on that side. If, on the other hand, the light is applied below the gauze, the gas will burn only on the underside.

It should be realised, of course, that it is only when the flame is produced steadily and for a limited time within the lamp that the quenching effect of the gauze will last. A strong current of air or an explosion within the lamp might easily carry the flame through a single gauze.

Dr. Clanny made an improvement on the lighting power of the Davy lamp by substituting for the lower portion of the gauze cover a glass cylinder to surround the flame, and then, to guard against air currents carrying the flame through the meshes, he invented a shield or bonnet.

The next step was the production by Dr. Meuseler of an inner cylinder (Fig. 11) to separate the products of combustion from the incoming fresh air, and so improve the illumination.

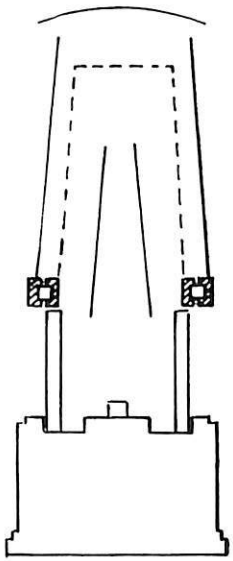


FIG. 11

Further researches were carried out by Marsaut, the French engineer, who produced a lamp having two gauzes, the inner gauze conical, and the outer one cylindrical or conical with a lesser slope than the inner one. The air space between the gauzes, being filled with the practically inert products of combustion, makes an effective buffer against an explosion carrying through from inside the lamp.

Most modern flame safety lamps are similar in their essentials to the Meuseler or the Marsaut lamps, though many minor improvements have been effected.

ELECTRIC SAFETY LAMPS

A new development in underground lighting took place in the latter end of the last century with the advent of a portable electric lamp. As a source of illumination electric lamps have generally a higher candle power than flame lamps, but it is a controversial point, which will not be entered upon here, as to whether electric lamps are a greater cause of miner's nystagmus than flame lamps.

Electric lamps are used extensively throughout this country, and their convenience in handling is a great asset to certain classes of underground workmen.

CONSTRUCTION OF SAFETY LAMPS

It might be interesting to quote here from the Mines Department Memorandum on the Test of Safety Lamps:

". . . the following requirements must be met, viz.:

(1) In the case of Flame Safety Lamps—

(*a*) It must be provided with double gauzes, or with some other adequate arrangements serving the same purpose. A single gauze lamp with a gauze cap will not be regarded as fulfilling this requirement. Every gauze must be of steel or best charcoal-annealed iron wire (or in the case of a lamp used for surveying purposes, copper wire) of not less than 28 S.W.G. (·0148 inch in diameter) with 28 meshes to the lineal inch (784 to the square inch).

(*b*) If lamp pillars are used the pillars must be so arranged that a straight line touching the exterior part of the consecutive pillars will not touch the glass.

(*c*) The lamp must be so constructed that it will not be possible to put together the component parts of the lamp without the gauze.

(*d*) The lamp must be provided with an efficient locking device to prevent the oil vessel, glass or bonnet from being removed by unauthorised persons, or loosened to such an extent that the safety of the lamp is impaired. Provision should also be made for taking up the play due to wear of the screw threads.

Note.—Lamps fitted with a screw lock and lamps in which the glass can under reasonable working conditions be loosened by forcing it round in its seating to such an

extent that the safety of the lamp is impaired, will not be regarded as complying with this requirement.

(2) In the case of Electric Safety Lamps—

(*a*) No liquid must escape from the battery when the lamp is turned upside down.

(*b*) The switch and other electrical contacts must be contained in flame-type enclosures.

(*c*) The lamp must be provided with an efficient locking device to prevent unauthorised persons from tampering with the electrical contacts."

The use of 20 mesh (27 SWG) gauges has been approved for a number of lamps.

RELIGHTING SAFETY LAMPS UNDERGROUND

A safety lamp (other than an electric hand lamp) must not be relighted except—

(*a*) At an appointed station which must not be in a return airway;

(*b*) By a competent person appointed in writing by the Manager for the purpose;

(*c*) After examination by the person appointed.

The lamp must also be examined by the appointed person after being re-lighted and before being issued.

Re-lighting apparatus must not be placed within 200 yards of any part of the working face, nor in a place where inflammable gas is likely to accumulate.

NO. 3 DAVIS-BOSS LAMP

Specially designed for gas testing, this lamp, made by John Davis & Son (Derby) Ltd., is issued for use by officials only. Fig. 12 shows the lamp in perspective. It is mainly constructed of aluminium, with a brass oil vessel. When not being used for gas testing the fresh air feed is fixed at B. When about to make tests the collar at B should be turned from left to right; this changes the entire feed to the

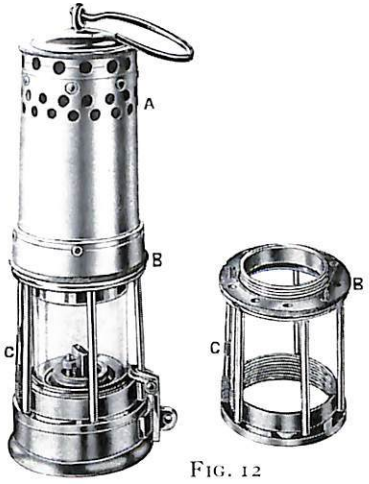


FIG. 12

upper intake holes at A, 1½ inches from the top of the lamp, and so ensures the detection of a very thin layer of gas near the roof. The normal feed is regained by drawing down the locking pillar C, which allows the collar to spring back. The change can be rapidly effected when there is a danger of the light being lost through an excess of gas entering at A.

The lamp is fitted with either lead plug or magnetic lock.

HAILWOOD NO. 01 SAFETY LAMP

This lamp is manufactured by Messrs. Hailwood & Ackroyd Ltd. It is fitted with two gauzes and either magnetic or lead rivet lock. It may be lit in the ordinary way, or by electricity.

The magnetic locking device is shown in Fig. 13. The glass-holding ring *a*, provided with ratchet teeth, engages with the iron bolt *b*, held in the up position by a strong spring *d* resting on a slidable iron guard plug *e*.

FIG. 13

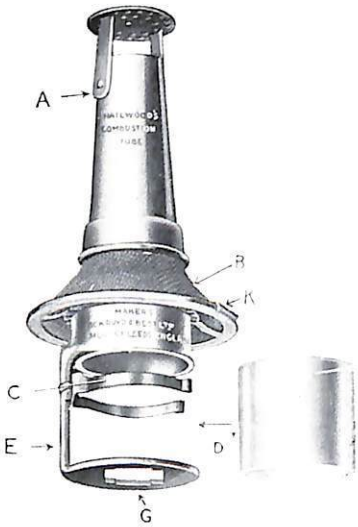


FIG. 14

To open, place the lamp on the electro-magnet supplied for the purpose, so that the pole of the magnet rod comes into contact with the guard *e*; it will press up and magnetise the guard and get a magnetic grip on the lock bolt *b*. Depression of the electro-magnet pedal draws down the guard plug and with it the lock bolt, releasing it from the ratchet. The lamp top may then be unscrewed from the oil vessel.

To lock the lamp, screw home the vessel, causing the lock bolt to click over the ratchet teeth of the glass ring.

These makers also produce a combustion tube lamp, the internal fittings of which are seen in Fig. 14. The main body is the standard Hailwood No. 01 lamp, but the usual inner gauze is replaced by a combustion tube and inner glass. Incoming air enters the usual outer gauze, passes through the gauze cone B and down between the inner and outer glass, and impinges on the flame at aperture A. Very good combustion and a clear light is obtained from this lamp, and the flame is not readily extinguished when the lamp is tilted.

BIFOLD BURNER MARSAUT LAMP

Manufactured by J. H. Naylor Ltd., the Bifold Burner lamp (Fig. 15) is of the Marsaut type, and has two gauzes. The locking

FIG. 15

device consists either of a lead rivet with the usual hasp and staple arrangement, or of a magnetic lock. Once the lamp is locked with the latter device it requires a powerful electro-magnet to open it.

It is fitted with the necessary arrangements for lighting electrically, so that it can be relighted underground where a relighting apparatus is available.

This lamp burns paraffin and is specially designed for gas detection. It is provided with a means of positive flame regulation, *i.e.* the wicks do not move up and down but are quite fixed, and the burner tubes slide over the wicks. It is easy to obtain two very small flames showing hardly any white apex, and to maintain them at the same height for many hours without readjustment.

When the flames are increased to their full size they join to give a good steady light.

PRESTWICH PATENT PROTECTOR LAMP

The Protector Lamp & Lighting Co. Ltd. of Eccles, Manchester, supply the well-known Prestwich Patent Protector Lamp. The details of its construction are shown in Fig. 16, which is self-explanatory.

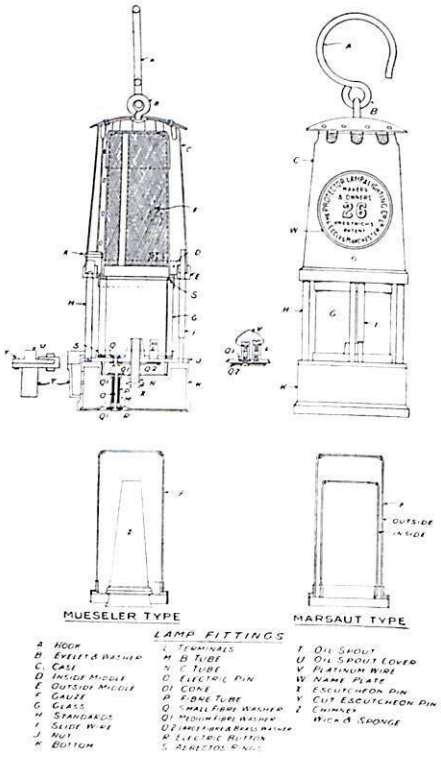


FIG. 16

CAMBRIAN NO. 1 C. G. LAMP

This lamp (Fig. 17) is made by Messrs. E. Thomas & Williams Limited, Cambrian Lamp Works, Aberdare. It is of the combustion tube type. The inner glass may be supported by a specially constructed burner screw or suspended by a spring clip from the combustion tube. The bonnet, or shield, is of rivetted steel furnished with outlet holes immediately below the crown, and so arranged that the bottoms of the holes are above the top of the gauze. The double

FIG. 17

gauzes are fitted either of 28 mesh or 20 mesh. It burns mineral colza oil, and has a candle power of $1\frac{1}{2}$ to $1\frac{3}{4}$. The lamp is arranged to be lighted electrically.

The lamp is made in brass and iron, brass, or aluminium, and weighs about 3 lb., and half this weight in aluminium.

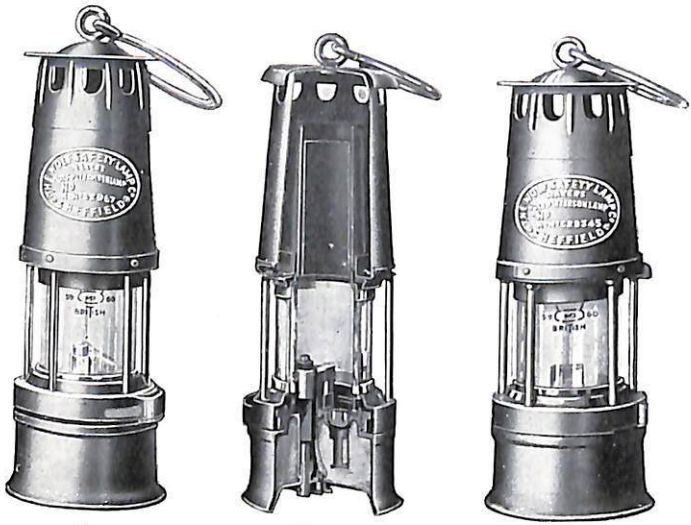
WOLF-PATTERSON LAMP

Made by the Wolf Safety Lamp Co. (Wm. Maurice) Ltd. of Sheffield, the Wolf-Patterson lamp is illustrated in Fig. 18, where the lamp is shown in perspective and in section.

In these lamps the air normally enters the space between the lamp vessel and the lamp top immediately below the screwed joint.

It passes thence through a double gauze ring direct to the flame, the products of combustion going upwards through the two gauzes and out by the openings at the top of the lamp. When, however, the lamp is to be used for gas testing, the bottom air inlet and the auxiliary air inlet at the base of the bonnet may be closed by moving levers as shown on the left of A.

An examination is first made with all air inlets open. If there is sufficient fire-damp in the air it will be indicated. If there is no indication the bottom air inlet is closed and another test made. A third test, if thought necessary, can then be made with both inlets



A

FIG. 18

closed. If there is a low percentage of gas it will be taken in at the top of the lamp and be indicated accordingly. The air inlets are, of course, opened again after having completed the examination.

It will be seen from the section view that there is no liquid fuel in Wolf lamps, the spirit being completely absorbed by a filling of cotton wool. These lamps are consequently not greasy or dirty to handle.

A screwed plug with leather washer closes the filling hole through which the lamp is charged, and provided the washer is sound and the plug well screwed down, there can be no leakage of vapour. The

wick is thin and flat, and $\frac{5}{8}$ inch wide. It is fitted in an inner sliding tube which moves up or down by rotating an adjusting screw in the base of the lamp. Since there is no incrustation on a wick burning spirit, the flame can always be brought to a standard position.

In the section view the lamp is shown provided with means of electric ignition from an external source.

THE OLDHAM HEWERS TYPE ELECTRIC HAND LAMP

Manufactured by Oldham and Son Ltd., Denton, near Manchester, this lamp consists of a tinned steel case as shown in Fig. 19. The

FIG. 19

glass has a solid top and the light is given from 1 candle power metallic filament bulb giving a continuous light for 9 to 10 hours.

The accumulator is a 2 volt lead type in a cylindrical celluloid box. Contact between the bulb and the terminals of the accumulator is made by turning the base of the lamp.

CEAG CAP LAMP

Electric cap lamps are very useful in many ways in pit work. Fig. 20 shows the cap lamp made by Ceag Ltd.

The accumulator is carried in an aluminium case on the back, supported by a leather belt. The head piece, which is carried in the cap by a strip, is connected to the accumulator by a flexible cab tyre cable. This design permits the wearer to have both hands free and a strong light can be shed in the desired direction as the wearer's head is turned.

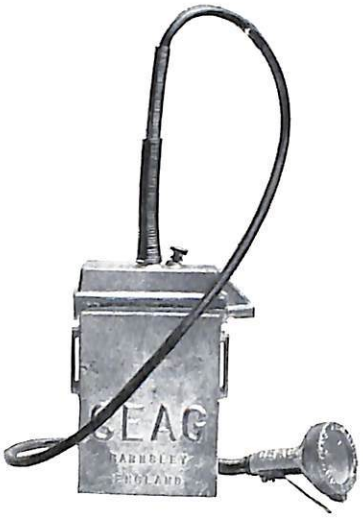


FIG. 20

A rectangular accumulator is used giving the minimum projection from the back. The action of closing the lid connects the accumulator, and locks the case if magnetic locking is fitted. In the case of a lead rivet lock, the usual rivet seals the case and an additional lock is fitted to the headpiece. The headpiece contains a patent fuse, which operates if the bulb is broken and isolates the bulb and all exposed parts.

When used continuously the lamp will burn from 10 to 12 hours but on intermittent use this period is increased.

Chapter VII

EXPLOSIVES AND THE REGULATIONS REGARDING THEIR USE

COMMERCIAL explosives are solid substances capable of being very rapidly converted, either totally or partially, into a gaseous state. It is the great and sudden change in volume of the substance which gives the explosive force.

There are two main divisions of explosives, low explosives and high explosives. In the former, the change to the gaseous state takes place much more slowly than in the latter.

LOW explosives used in mining are Black Powder (gunpowder) and the permitted explosive, Bobbinite, manufactured by Curtis's & Harvey Ltd. Because of their slow, heaving action these explosives are very suitable for coal getting where the amount of round coal produced is a first consideration. The use of these explosives is, however, confined to certain classes of mines.

There is a very wide range of high explosives manufactured by Nobel Industries Ltd. and it should always be possible to choose an explosive suitable for the work on hand. In general, high explosives fall into two classes, the gelatinous type, which contain a high percentage of nitroglycerine, and the powder type containing a relatively small percentage of, or no, nitroglycerine. A representative selection is given below.

GELATINOUS EXPLOSIVES

Blasting Gelatine and its low freezing equivalent, Polar Blasting Gelatine, are the strongest of all known blasting explosives. They are suitable for use in the hardest rock, such as quartz, haematite, etc. They possess the property of a high resistance to the action of water.

Gelatine Dynamite and Polar Gelatine Dynamite come next to the Blasting Gelatines in strength, are extensively used in ironstone mining, and are very suitable for hard rock work. They also possess a good degree of water resistance.

Gelignite and the low freezing Arctic Gelignite are standard explosives, and can be used for many kinds of blasting work. Their use extends from coal blasting in certain coal mines to quarry and tunnel work.

Gelignite 50 per cent. N.G. and the low freezing Arctic Gelignite No. 2 are modifications for use where a weaker explosive than the standard gelignite can be economically used.

POWDER EXPLOSIVES

Where a mild action is desired and high density is not essential, the explosives in this group are found useful. Representative explosives of this class are:

Polar Rockite, Ammonal, and Blasting Abelite.

PERMITTED EXPLOSIVES

A table on page 51 gives a list of permitted explosives made by Nobel Industries Ltd. and the purposes for which they are best suited.

The term "permitted explosives" is applied to those explosives which are officially sanctioned for use in all coal mines in which inflammable gas has been found within the previous three months in such quantity as to be indicative of danger, and in all coal mines which are not naturally wet throughout.

Before being sanctioned explosives have to undergo the official gallery test, which consists of firing shots from a gun, without tamping, into a mixture of gas and air, until the largest charge which can be fired without igniting the mixture is found. Further shots are then fired—beginning with this charge, and in the event of an ignition, reducing the charge—until five shots of the same weight have been fired without igniting the mixture.

With the charge so determined additional shots are fired into fine coal dust, and the same procedure adopted until five shots of the same weight have been fired without igniting the coal dust.

The lower of the charges determined is known as the "Maximum Charge," and if this is less than eight ounces the explosive does not pass the test. No explosive is tested over $2\frac{1}{2}$ lb.

To obtain an indication of the strength of the explosives, shots are also fired at a ballistic pendulum which consists of a heavy steel mortar swung from a knife edge. The backward swing of this mortar is measured in inches and recorded in comparison with that given by an equal weight of standard Gelignite. It should be understood, however, that strength tests of this nature do not always give an

(*Contd. on page 52*)

PERMITTED EXPLOSIVES

Class and Name of Explosive	Charge Limit (oz.)	Uses and General Remarks
Gelatines:		
Samsonite No. 3 ..	24	For drift cutting, hard coal and ripping.
Super Rippite No. 2 ..	26	
Saxonite	18	Specially recommended when a single explosive is required both for coal getting, brushing or ripping purposes.
*Polar Saxonite	20	
Powder Explosives:		
Dynobel No. 3	18	For drift cutting, hard coal and ripping.
*Polar Dynobel	20	
Rex Powder	20	For hard splint coal and moderate ripping.
*Polar Rex	20	
Stomonal No. 1 ..	20	
Super-Cliffite No. 3 ..	22	
*Polar Super-Cliffite ..	20	
Thames Powder No. 2 ..	22	For moderately hard coal and moderate ripping.
*Polar Thames Powder ..	26	
Viking Powder No. 2 ..	18	For hard splint coal and moderate ripping.
*Polar Viking	22	
Non-Nitro-glycerine Explosives:		
*Bellite No. 1	20	For all kinds of colliery work.
*Denaby Powder	18	
*Roburite No. 4	18	
*Gathurst Powder ..	24	For coal getting.
*Negro Powder No. 2 ..	38	
Gunpowder:		
*Bobbinite	None	For coal getting. Damp proof. The only permitted gunpowder. No Detonator required.

* Require no thawing.

Note.—BOBBINITE. By an order of 11th November, 1927, this explosive will cease to be available after the end of 1931, and is not to be introduced to any new places in the intervening years.

accurate measure of the capabilities of an explosive in practical use. If an appreciable amount of the charge is left unexploded, the explosive does not pass the test.

EXPLOSIVES IN COAL MINES ORDER

In pursuance of Section 61 of the Coal Mines Act, 1911, an Explosives in Coal Mines Order was issued on 1st September, 1913, which has been amended to some extent since that date. The order is in three main parts. Part I deals with general provisions which apply to all mines, gassy or otherwise. Part II contains special provisions for gassy, dry and dusty mines, etc., and Part III makes certain supplemental provisions. There are also five Schedules giving lists of Permitted Explosives, etc.

EXPLOSIVES

Explosives to be used in shotfiring must be kept on the surface in one or other of the various kinds of storage places authorised by the Explosives Act, 1875, from which they can be obtained, unless it is known that the preceding workman in the working place has a surplus to hand over. The explosive must be in cartridge form, and in diameters of $\frac{7}{8}$ inch, $1\frac{1}{4}$ inches, $1\frac{7}{16}$ inches, $1\frac{3}{4}$ inches, or 2 inches. In the Ironstone mines in the Cleveland district cartridges $1\frac{3}{16}$ inches in diameter may be used. This standardisation of cartridge sizes was decided upon by the Home Office authorities with a view to limiting the large number of different sizes of cartridges at one time manufactured. Explosives must be taken underground in a secure canister containing not more than 5 lb., and a person must not have in use at one time in any one place more than one of such canisters. Further information regarding storage accommodation and actual details of magazine construction can be obtained from the Nobel booklet entitled "The Storage of Explosives."

FROZEN EXPLOSIVES

(*See following paragraph for Low Freezing Explosives*)

If the explosives are frozen, a condition in which those containing nitroglycerine are liable to be found when the temperature is below 45°F., they should be thawed in a warming pan specially constructed for the purpose, and provided by the owner, agent or manager of the mine.

It is sometimes found that explosives have frozen on the outside only, and these are readily thawed. If, however, the cartridges have been completely frozen, care should be taken that thawing is complete before use. Thawing takes place from the outside of the cartridge and works towards the centre, so there is some risk of a core of frozen material even when outwardly the cartridge appears to be in good condition. *Frozen explosives must be handled very carefully and must never be used in a charge.*

Certain explosives lose much of their effectiveness when chilled though not actually frozen. In cases of doubt such explosives should be treated as if they were frozen. Nobel Industries Ltd. are prepared on application to advise users as to the best methods to be followed out in heating magazines to guard against freezing of explosives.

LOW FREEZING EXPLOSIVES

Whilst the regulations regarding the use of warming pans still hold, Nobel Industries Ltd. have developed new types of low freezing explosives which are not in the least likely to freeze in the climatic conditions prevailing in Britain. Reference is made to these on page 49, and in list contained on page 51 (Permitted Explosives).

SQUIBS

In a naked light mine, where the use of permitted explosives is not compulsory, squibs may be used to fire gunpowder shots. When used, they must be taken into the mine in a suitable metal case separate from any other explosive. It is advisable also to keep them separate from any other articles, so as to avoid damage by blows or shocks in transit.

To use a squib, the powder is placed at the back of the shothole and a long copper needle is inserted so that its point is buried in the charge. The hole is filled to the mouth with stiff clay tamping and the needle withdrawn. The squib is placed in the mouth of the opening left by the needle and lighted at the extreme outer end. It burns slowly for a short time and then a train of sparks shoots to the back of the hole and ignites the powder. A squib which has gone out must not be relighted.

SAFETY FUSE

This is a means by which ignition is carried to gunpowder charges, or to detonators, where the charge is high explosive. Safety fuse supplied by Bickford Smith & Co. and Nobel Explosives Co. Ltd. for use

in coal mines is made up of a core of gunpowder protected by not less than three coverings of thread, or by not less than two coverings of thread and one of tape or gutta-percha. It burns at the rate of about 90 seconds to the yard, and its burning speed must not vary more than 10 seconds above or below that rate.

DETONATORS, ELECTRIC DETONATORS AND DELAY ACTION DETONATORS

Nobel ordinary detonators are supplied in various sizes up to No. 8 and Nobel electric detonators in sizes 6, 7 and 8. The standard size

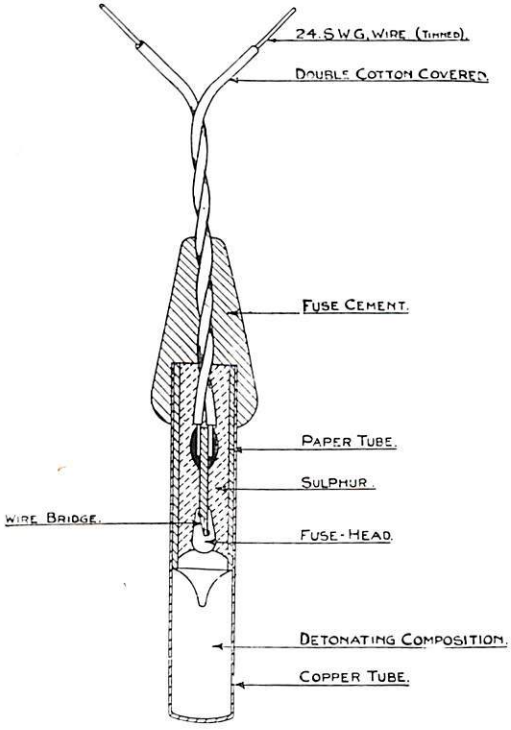


FIG. 21

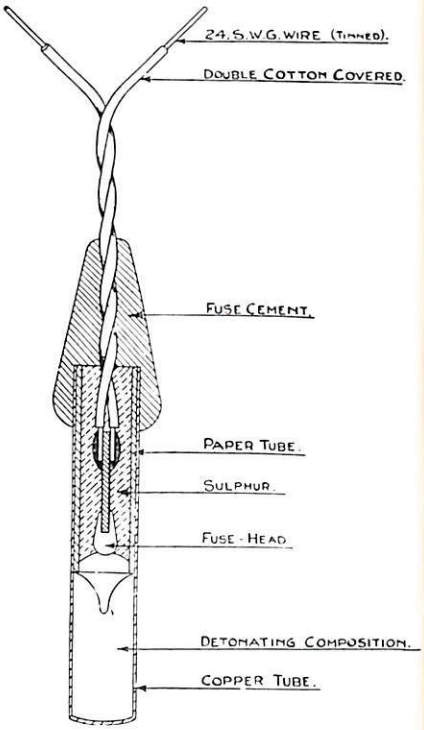


FIG. 22

in both kinds is No. 6. So far as Nobel explosives are concerned nothing more than a No. 6 Detonator is really required.

Detonators are obtainable in either copper or aluminium tubes. In accord with the Explosives in Coal Mines Order of 10th November,

1926, copper tubes only must be used where permitted explosives need to be employed.

Varying lengths of wire are fitted to electric detonators to suit the work for which they are to be used.

There are two types of electric detonators in general use, viz. low tension and high tension, in both of which the detonating composition is ignited by flashing mixture. In the low tension electric detonators (Fig. 21), the flashing mixture is ignited by a small metal bridge which becomes heated when the current is passed through the wires. In the high tension electric detonators (Fig. 22) the ignition is effected by the passage of the electric current through the flashing mixture itself. Apart from the box markings, low and high tension electric detonators are distinguished in the colouring of the lead wires. Low tension have two white wires, and high tension have one white and one red wire.

For single shotfiring, either high or low tension detonators are suitable, but low tension ought always to be used for firing two or more shots simultaneously.

Where the workings are wet, or the explosive charges and wire connections are under water, as, for example, in most sinking operations, submarine electric detonators or submarine delay action detonators should be used. This class of electric detonator is also suitable for use under very heavy water pressure. For submarine and wet workings low tension electric detonators should always be employed.

Electric powder fuses are made for use with Bobbinite and gunpowder.

Detonators must not be stored underground and they must be under the sole control of the Manager, or, as is more commonly the case, under the control of someone specially authorised in writing by the Manager. In mines where permitted explosives must be used, the electric detonators must only be issued to appointed shot-firers. In other mines detonators may be issued to shot-firers, firemen or underground officials superior to the fireman, provided these persons have the written authority of the Manager to carry detonators.

Detonators carried underground must be kept, until about to be used, in a locked case or box used for detonators only.

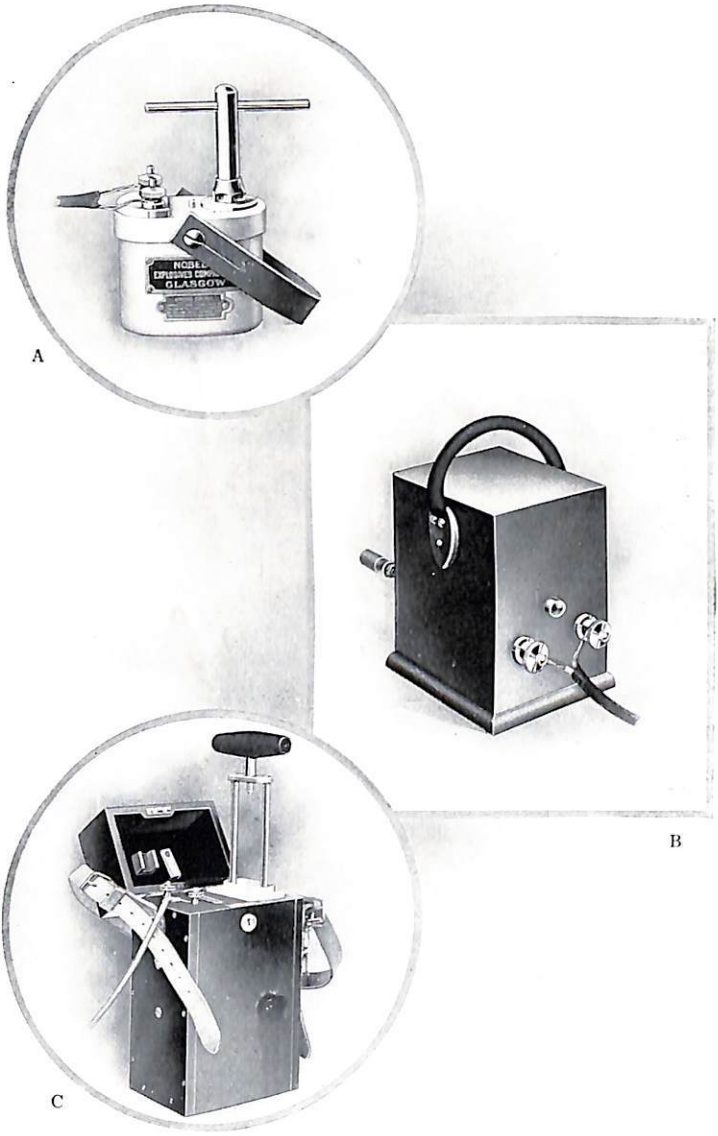


FIG. 23

EXPLODERS

The type of electrical shot-firing apparatus to be recommended depends on whether high or low tension detonators are used, and on the number of shots to be fired simultaneously. High tension exploders, or batteries, as they are sometimes called, are, of course, used with high tension detonators in single shot firing. Low tension batteries for ordinary colliery work are of two kinds. One is a magneto exploder (Fig. 23A) operated by a half turn of the handle. The firing contact is made at the end of the travel of the handle, on release of which the contact is automatically broken. This exploder is suitable for single shots or for two shots in series. The other exploder (Fig. 23B) suitable for single shots or for up to five or six shots in series, is operated by a handle and push button. The push button is depressed while the handle is being rapidly turned.

Where a large number of shots have to be fired simultaneously, as in sinking pits or driving large stone drifts, a dynamo exploder, actuated by a rack and pinion, of the type shown in Fig. 23C, is used. This exploder will fire up to 50 shots in series. Exploders for mines where permitted explosives must be used, require to be so enclosed as to afford reasonable security against ignition of inflammable gas. The exploders shown in above illustrations meet requirements in this respect.

CABLES AND GALVANOMETERS

For electric shot-firing two-core cables covered with insulating material and protected against mechanical damage must be used. The cable must not be less than 20 yards in length.

A cable may be defective in either of two ways:

(*a*) One of the conductors may be broken.

(*b*) The conductors may be in contact, in which case the cable is "short circuited" and the current will not reach the electric detonator.

To prove that the cable is satisfactory, two tests are necessary:

(*a*) Join the two conductors together at one end of the cable. Keep the conductors at the other end apart and press them on the terminals of a galvanometer. If the needle moves, the

conductors of the cable are unbroken; if the needle remains steady, one at least of the conductors is broken.

FIG. 24

(*b*) Separate the two conductors at both ends of the cable and press those at one end on the terminals of the galvanometer. If the needle remains steady, the cable is all right; if it moves there is a short circuit which will have to be put right.

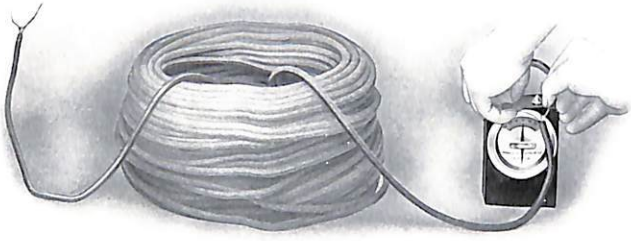


FIG. 25

Galvanometers are sometimes used when testing low tension electric detonators before use. When this is being done the detonator itself should be inserted in an iron pipe or similar place as a protection in case the galvanometer should be faulty and ignite the detonator.

Galvanometers are also used to test the continuity of a series of shots; in sinking pits the practice is common. It sometimes happens that the test is applied from just outside the hole to single shots when the charge is in position. This is a dangerous practice, and the

test should only be carried out when the tester and all other persons are at a safe distance away, and out of danger, in the event of a shot being exploded.

PREPARING AND FIRING THE CHARGE

PRIMING

When safety fuse is used, the fuse should be cut straight across with a sharp knife or fuse cutter, both of which should be kept clean. A freshly cut end of fuse should be used for insertion in the detonator and care should be taken not to use damp fuse. Shake all the sawdust

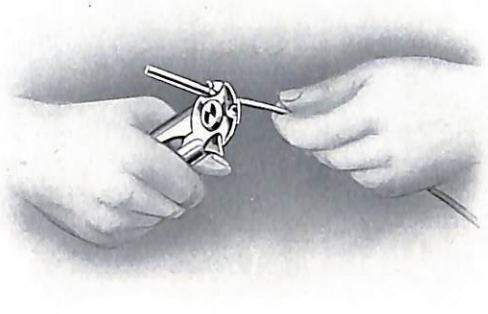


FIG. 26

carefully out of the detonator and slip it over the end of the fuse until the composition and fuse are in contact. Never screw the fuse against the composition. Crimp the detonator gently but securely on to the

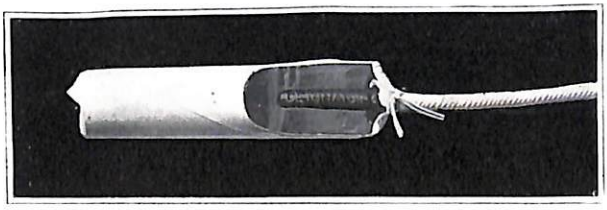


FIG. 27

fuse by means of approved detonator nippers. For wet work, use the types of fuse specially made for the purpose, and make the joint

between detonator and fuse thoroughly waterproof by means of bituminous or similar material. To prime a cartridge with detonator and safety fuse, open the cartridge at one end, make a hole with a small stick or with the attachment on the handle of the crimping

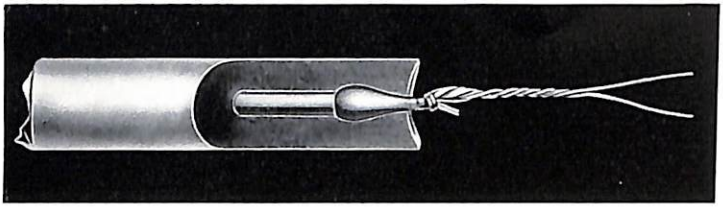


FIG. 28

pliers in the opened out end, and push the detonator into the hole leaving one third of the detonator projecting. Tie the cartridge paper firmly round the detonator. If the detonator is completely buried there is a danger of the explosive being set on fire by the fuse. When priming with an electric detonator, the latter should be buried in the explosive and the cartridge paper tied round the detonator wires.

CHARGING

Before any shot is charged the direction of the hole must, where possible, be distinctly marked on the roof or other convenient place. This serves as a guide in the event of a miss-fire.

The person firing the shot must satisfy himself that the charge is placed in a properly drilled and placed shot hole, the diameter of which must be at least $\frac{1}{8}$ inch more than the diameter of the cartridges it is intended to use. Before charging, the hole should be properly cleaned, and for this purpose a $\frac{3}{8}$ inch copper rod with the ends flattened and turned at right angles to the line of the rod is very suitable. No iron or steel scraper is allowed in a mine.

The cartridges should be inserted one at a time and each pushed home with a wooden tamping rod. *The primer cartridge, which should be the last to be inserted, should be pressed very gently into the hole until it rests against the charge, and the end of the cartridge containing the detonator should be outermost*, as shown in Fig. 29. With the detonator in this position direct initiation is given to the charge, and the greatest work is done at the back of the hole where it is required. A not uncommon practice is to place the primer with

the detonator directed towards the stemming. *This inverse initiation causes the strongest detonation wave to move against the stemming, is liable to cause blown out shots, and to leave unexploded cartridges at the back of the borehole. Insertion of the detonator in the middle of a charge, even though the detonator is directed to the bottom of the charge, tends to have a similar effect. Both practices are incorrect, apart from very exceptional conditions, and should be avoided.*

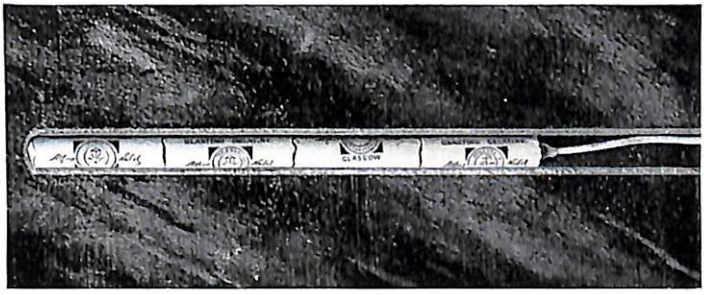


FIG. 29

Sand or clay, preferably clay, never coal dust, should be used for tamping, inserting several inches loosely and then ramming hard. During tamping the detonator wires or safety fuse should be held to one side to facilitate the action of the tamping rod and prevent damage. Explosives must not be forcibly pressed into the hole, and a charged hole must not have the stemming, explosive, or detonator leads, removed, unless an approved appliance is used.

FIRING

The person firing the shot must see that all persons in the vicinity have been warned and are taking shelter, and he himself must also take proper shelter. He must also take suitable steps to prevent any persons approaching the shot.

When fuse is used, it may be ignited by means of patent igniters or by naked lights. These igniters include Fusees, Port Fires, and "Cheesa" Sticks. In safety lamp mines an approved igniter must be used, which, when attached to the fuse, forms a completely closed chamber. While charging a shot in a naked light mine, no one is

allowed to smoke or have a naked light within four feet of the shot-hole or explosive. Definitions of the class of mine where Safety Lamps must be used are given in Coal Mines Act, 1911, Section 32.

A person firing shots electrically must be appointed in writing by the Manager to do so. All exploders must have a removable handle, and it is a wise and compulsory precaution that the handle should be kept at all times in the custody of the authorised person whilst on duty.

The shot-firing cable, the length of which should be not less than 20 yards, should next be run out, care being taken to keep clear of lighting or power cables. The ends of the detonator wires should be scraped clean and bright, and connected to the cleaned bared strands of the cable. In making the connections, the ends of the detonator wire and cable wire should be carefully twisted together to ensure perfect metallic contact. Care should be taken not to kink the detonator leads or the cable.

The next step is to connect the outer end of the cable to the terminals of the exploder. If an exploder of the type shown in Fig. 23A is used, the shot is fired by inserting the handle and turning it rapidly to the stop position. If the other type Fig. 23B is used, the handle is inserted and turned as rapidly as possible: *while the handle is going at full speed* the button is pressed.

Special Caution: In all cases the cable should be disconnected from the exploder immediately after the blast.

The person firing the shot must make a careful examination of the place after firing and see that it is safe in all respects. The examination should not be carried out until the place is free enough from fumes not to affect the vision. A test should be made for gas, and the roof and sides tested with a pick shaft or similar tool for loose material. The immediate vicinity of the shot-hole should be examined to see that the shot has functioned satisfactorily.

MISS-FIRES

A miss-fired shot is a most awkward occurrence, and requires the greatest care in dealing with it. With Nobel detonators and explosives such an occurrence is comparatively rare, but if a shot misses fire the regulations require that "The person firing the shot shall not himself approach or allow any other person to approach nor shall any person knowingly approach the shothole until an interval has elapsed of not

less than ten minutes in the case of shots fired by electricity or by a squib, and not less than an hour in the case of shots fired by other means."

"If the person firing the shot has occasion to leave the place, he shall fence off the place before leaving, and attach to each fence a danger board indicating the presence of a miss-fired shot."

Where the firing is done electrically, the cable must be disconnected and the handle removed from the exploder. After the lapse of the stipulated time a thorough examination of the cable and connections should be made, and if the cable or a connection is faulty the defect should be remedied and the shot fired.

Except in the case of a faulty cable or connection, a second hole must be drilled not less than 12 inches from the first and as nearly parallel to it as is practicable.

Before firing the new hole, the detonator leads or fuse, as the case may be, of the miss-fired shot must be attached by a string to a convenient prop so as to assist in its recovery. The material brought down must be carefully gone over with the hands before other work is resumed in the place, to discover the detonator and explosive of the shot that miss-fired. If the detonator and charge are not found, the coal or stone must be loaded and sent to the surface in a specially marked tub.

The Regulations further require that "Should the miss-fire shot not be dislodged by the second shot, further holes must be drilled and the same precautions taken as aforesaid."

"The person or persons firing the shots shall report the circumstances to the Manager or Under Manager without delay, and the number of cartridges, if any, which have not been found, and hand to him the detonator and charge, if found."

SHOTFIRING IN GASSY AND DRY AND DUSTY MINES

Part II of the Explosives in Coal Mines Order sets out special provisions to apply to mines in which permitted explosives are required to be used.

Permitted explosives must be used in all coal mines in which inflammable gas has been found within the previous three months in such quantity as to be indicative of danger, and in all coal mines which are not naturally wet throughout. A list of the permitted explosives manufactured by Nobel Industries Ltd. is given on page 51.

In all such mines the following regulations are enforced:

Shotfirers must be appointed in writing by the Manager to fire shots. A shotfirer appointed in pursuance of this order must have the same underground experience as is required of a fireman, but he may be appointed when twenty-three years old, whereas a fireman must be twenty-five or upwards, unless he holds a first or second class Manager's certificate. He must also possess a shotfirer's certificate. To obtain a certificate the shotfirer must be able to test for gas and have the same standard of eyesight as is required of candidates for the fireman's certificate. A shotfirer's wages must not depend on the amount of coal produced.

The shotfirer must keep a daily record of the number of shots fired by him, the number of miss-fired shots, if any, and the number of cartridges in each shot. A specimen report form is shown on page 81.

Before a coal shot is fired the coal must be holed to a depth greater than the depth of the shot hole, except in anthracite mines or mines exempted by the Inspector of the Division for special reasons.

The shotfirer must not allow a hole to be charged if any breaks run along or across it, except in stone drifts, and then only by the written permission of the Manager or Under Manager. He must charge and stem all shots himself, or supervise the charging and stemming.

All accessible places within 20 yards of the shot hole must be examined and found free from inflammable gas and safe in all respects before the shot is fired. If there are any breaks or cavities within that radius, other than in the waste, which cannot be examined and which may contain gas, the shot must not be fired. This examination for gas need not, of course, be carried out in a mine in which inflammable gas is unknown.

A shot must not be fired until the floor, roof and sides of all places within 5 yards of the shot hole have been thoroughly treated either with water or with incombustible dust, and if the shot hole is within 10 yards of a road which is ordinarily treated in either of these ways then the treatment must be made continuous from the road to the hole. Such treatment need not be carried out if the Manager gives the shotfirer written permission to dispense with the precaution because of the natural conditions of his part of the mine.

Except in driving stone drifts and in sinking pits, two or more shots must not be fired in the same place simultaneously, and the

test for gas must be carried out immediately before the firing of each shot. If two or more shot holes have been placed in such a manner that the firing of one shot would be liable to relieve any part of the work to be done by another shot, each shot must be fired before any of the others is charged. This requirement as to charging does not apply in the case of coal shots in a long-wall face where the firing is done between shifts, if its observance would necessitate the firing of any such shot during a working shift.

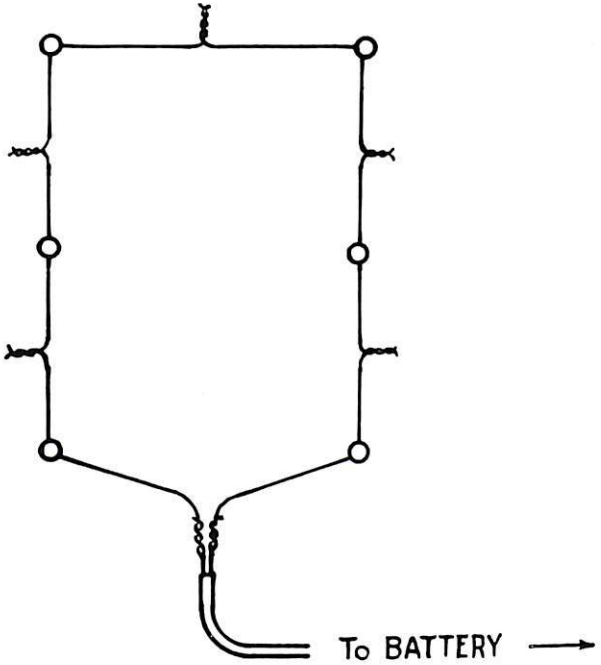


FIG. 30

In driving stone drifts and in sinking pits rounds of shots may be fired, but in the former the number of shots which may be fired simultaneously must not exceed three, unless fired electrically in series.

To connect a number of holes in series one wire from the first hole is connected to one wire from the second, and the other wire from the second hole to a wire from the third, and so on. When the holes are

interconnected there remains one wire from the first hole and one from the last hole. These wires are connected one to each of the cable lead wires as shown in Fig. 30.

When firing in parallel one wire from each hole is connected to one of the lead wires of the cable, and the other wire from each hole is connected to the other cable lead wire. Fig. 31.

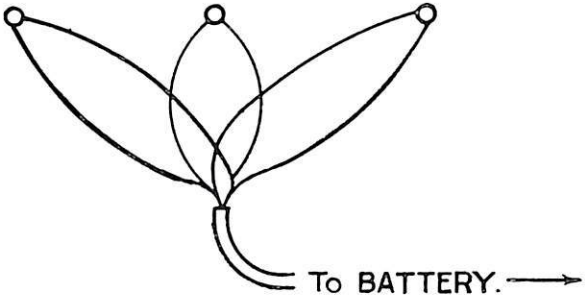


FIG. 31

This method of firing is also dealt with in Nobel Industries Ltd.'s booklet, "Blasting in Collieries and Hints on Electric Shotfiring."

All shots must be fired electrically by means of a magneto-electrical apparatus.

HAULAGE ROADS AND AIRWAYS

In all coal mines which are not naturally wet throughout, the special permission of the Manager in writing is required before a shot is fired in the main haulage roads, or intake airways. It is also necessary in such a case to withdraw all men from the seam in which the shot is to be fired and all other seams communicating with the shaft on the same level, except the few engaged in firing the shot and attending to machinery, horses, etc.

REGULATIONS ON SHAFT SINKING

The supplemental provisions in Part III of the Explosives in Coal Mines Order which affect a shotfirer are those relating to sinking operations.

When sinking or deepening shafts, detonators may be fitted to priming cartridges on the surface, provided the primed cartridges are

taken into the shaft in a receptacle, such as a felt bag, which will protect them from shock. Such priming must be carried out in a workshop detached from the magazine, and no other work may be carried on in the workshop whilst priming is being done.

Explosives must not be taken into the shaft until immediately before they are to be used.

All shots must be fired by means of a magneto-electrical apparatus.

The firing cable must not be coupled up to the detonator wires until the kettle, or hopper, is conveniently placed for the men in the shaft to enter, and the chargeman has received a signal from the surface that the engineman is ready to draw away on receipt of the signal to do so. *The cable must not be coupled to the exploder until all persons are in a place of safety.*

After a shot has been fired the chargeman shall not allow any person to descend until he himself has descended, accompanied, if necessary, by not more than two other persons, and has examined the place and found it to be safe in all respects. If the place is one in which inflammable gas has been found or is likely to be found, the examination shall be made with a locked safety lamp of a type which will indicate the presence of such gas.

THE EFFICIENT USE OF EXPLOSIVES

The main factors affecting the efficient use of explosives are (*a*) the kind of explosive, (*b*) the placing of the shot-hole, (*c*) the weight of the charge, (*d*) priming and (*e*) stemming.

(*a*) For permitted explosives, list is given on page 51, with particulars of the class of work for which the individual compounds are recommended. In the case of non-permitted explosives reference has already been made to various types and their uses (see pages 49 and 50). It should be recognised, however, that whilst in general the recommendations made are thoroughly reliable, there are conditions where practical application can be the only true guide. Nobel Industries Ltd. are always prepared to afford explosives users the benefits of the advice and service of their experts in case of need.

(*b*) Boring shot-holes in the direction that will get the maximum amount of work out of the explosive is something which is not always very carefully done. A common error when blasting coal out of the solid, *i.e.* grunching, is the placing of the hole straight into the coal.

The explosive in this case is too confined to do lateral work with the result that, as a rule, only a small cavity is blasted round the mouth of the bore-hole. When coal is being won by grunching the breaking-in shot should be set at an angle of about 45° to the line of the face. This angle should be increased with each succeeding shot (Fig. 32)

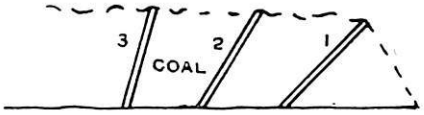


FIG. 32

until the hole is bored nearly at right angles to the face. Shooting off the solid is only allowed in mines where permitted explosives are not required to be used, and in anthracite mines or mines exempted by the Inspector of the Division.

Where the coal is holed by hand the undercut is never very deep. It is not an advantage, even where it is permissible, to have holes beyond the undercut. In Fig. 33, A shows the probable lines of fracture resulting from a shot where the hole has been bored beyond the

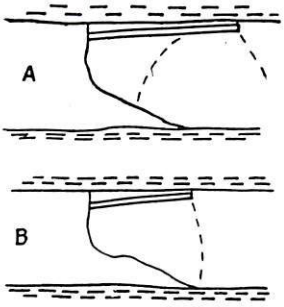


FIG. 33

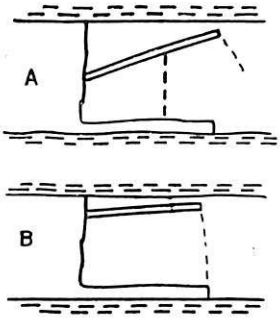


FIG. 34

undercut in a hand-holed place; Fig. 33, B shows the correct placing of the hole. In Fig. 34, A depicts another improper method of placing a shot-hole; the holes should be bored as shown in B.

In pillar and stall, or stoop and room, work, where the coal is machine cut and practically the same conditions are found from day

to day, it should be possible after a few trials to get the best method of placing the holes. Fig. 35 shows the position of holes for a stall, or room, 15 feet wide with the coal 6 feet thick. Fig. 36 shows the position when a hard dirt band runs through the coal.

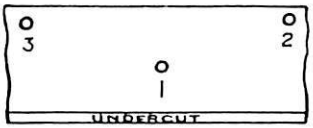


FIG. 35

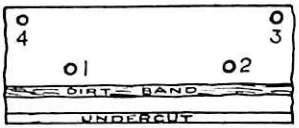


FIG. 36

Fig. 37 shows the method adopted in a room 15 feet wide by 5 feet 3 inches high in the Ell coal undercut 5 feet 6 inches in a Scottish colliery. The order of firing is shown in the diagram. The three top holes were 5 feet deep and the bottom holes 2 to 3 feet deep. The rib shot-holes were angled slightly up and in towards the rib, the usual practice being to start just below the parting between top and breast coal, and to finish just above the parting. Sometimes two bottom shots were used, sometimes only one. These shots were lightly charged but they served to make the stripping of the bottom coal a fairly easy operation.

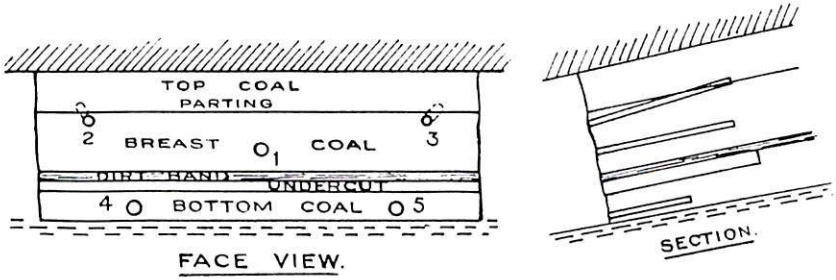


FIG. 37

Fig. 38 shows how the holes were placed in a heading 10 feet wide and 6 feet high, where the coal was 2 feet 9 inches thick and had a soft dirt band immediately above. The coal was undercut to a depth of 6 feet. It was found to be a distinct advantage to place the holes in the dirt band and a large percentage of lump coal was produced.

When the coal was filled out the ripping was blasted by holes placed as shown.

(*c*) The most economical weight of charge can only be arrived at by trial. A very common fault is overcharging. The miner, set to work in a new place, charges heavily for the first blast. He finds that the charge he has used brings down the coal, and he is content to use

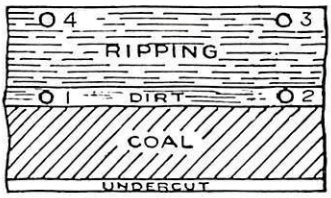


FIG. 38

that same weight of explosive in all subsequent work. If he could be induced to try reducing the charge, he would probably find that the coal could be brought down in better condition by the smaller quantity of explosive.

In the seam shown in Fig. 37 the charges found to give splendid results were—hole (1) 8 oz.; holes (2) and (3) 12 and 8 oz. respectively of Thames Powder No. 2. The band of dirt just above the undercut was somewhat hard to break: 2 oz. charges were usually sufficient for the bottom shot-holes.

The charges used in the heading in Fig. 38 were 12 oz. of Dynobel No. 3 in the shots to bring down the coal, and 14 to 16 oz. of the same explosive in the ripping shots.

In driving stone drifts the method of blasting depends on the lie of the strata, the hardness of the rock, and such other factors as the gradient of the drift and the type of boring machines available. Fig. 39 shows what would probably be a suitable round in a level drift 12 feet wide by 6 feet high, cutting through hard sandstone. The order of firing should be, first, the six centre shots simultaneously, next, the two side shots, followed by the three top shots, and, lastly, the three bottom shots.

The amount of lift that should be attempted in stone work varies, of course, but a common error is to try to get too much ground. In

general, the smaller the cartridge the shorter the lift should be. In the instance just mentioned, cartridges having a diameter of $1\frac{1}{4}$ inches

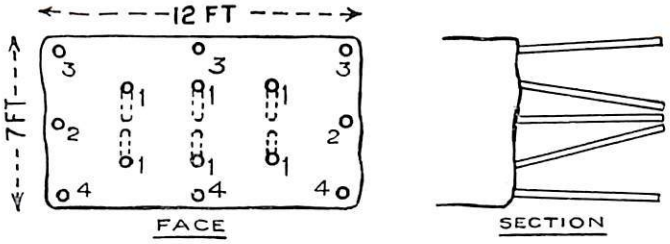


FIG. 39

would go with a 5 feet cut, and $1\frac{7}{16}$ inch cartridges with a cut of 5 feet 6 inches or 6 feet. To obtain a greater lift larger diameter cartridges would have to be used. This would mean a wider hole and consequent higher drilling cost, but this course is justifiable in some cases.

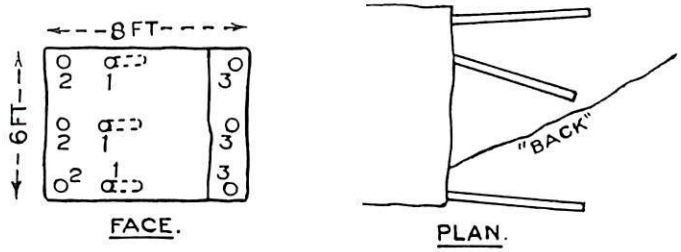


FIG. 40

So far as possible in all blasting work advantage should be taken of "backs" or "slips" and cleavage planes.

Fig. 40 shows in face view and plan the placing of holes in an 8 feet by 6 feet stone drift, where a vertical slip runs across the face. In mines where permitted explosives must be used, the written permission of the Manager or Under Manager must be obtained before shots are fired in a face containing breaks.

(*d*) Priming and (*e*) Stemming have been fully dealt with in pages 59 and 61.

Accidents

The following accidents have taken place in the handling and use of explosives in mines. They are extracted from the official reports.

I Frozen Explosives

(*a*) *Use of Frozen N.G. Explosives*

A Stone Miner was pushing a bunch of gelignite cartridges into a shot-hole with his copper scraper when they exploded and inflicted such severe injuries that he died early next day. Ten minutes before the accident he had complained to his mate that the cartridges were hard.

It is bad practice to *bunch cartridges*, and exceedingly dangerous to use them in a hard or frozen condition.

Cartridges of several sizes are made and the size should be chosen to suit the shot-hole. H.M. Inspectors' Report, Scot. Div., 1924.

(*b*) *Thawing of Explosives*

A Polish Miner received fatal injuries when he attempted to thaw frozen explosives underground on a heated shovel.

Apart from the foolhardiness of the act, the explosives should not have been issued to him in a frozen condition. H.M. Inspectors' Report, Scot. Div., 1925.

II Safety Fuse

(*a*) *Badly Timed Fuse*

A drawer lit a bursting shot in the solid. The shot exploded. A piece of shale was projected out and killed him before he had reached a place of safety. This accident was most probably due to error in estimating the fuse length necessary to ensure time for retreat. H.M. Inspectors' Report, Scot. Div., 1924.

III Firing

(*a*) *Properly Timed Fuse, but inadequate shelter*

A Miner having lit a shot in a cross measure drift failed to take adequate shelter. A man-hole was available 35 yards from the shot. The Miner, being hit by a flying stone, sustained injuries from which he died later. H.M. Inspectors' Report, Cardiff and Newport Div., 1924.

(*b*) *Carelessness in use of Exploder*

A Shotfirer charged three shot-holes in the top canch of a gateway on a long wall face. He fired the first shot, taking shelter in an adjoining gateway, and was accompanied there by the stonemen who were engaged at the canch. The Shotfirer proceeded to couple up the cable from the shotfiring battery to the second shot, and had also left the handle on the battery. After coupling up the cable to the detonator leads of the second shot he was heard to give a warning shout of "fire." One of the stonemen, not authorised to act as a shotfirer, apparently took the warning shout of "fire" as an instruction to him to fire the shot, and illegally turned the handle of the battery. The shot exploded whilst the authorised shotfirer was still standing at the shot-hole, and he received severe injuries to his head, which proved fatal two days later. This accident would probably not have taken place if the handle of the battery had been removed and the cable disconnected, prior to connecting up the second shot. H.M. Inspectors' Report, Northern Division, 1924.

(*c*) *Improperly placed shot-hole*

A Coal Hewer charged a shot-hole in the solid coal with 1 lb. of gunpowder, lit the fuse and retired, but failed to take proper shelter. The hole was *improperly placed* and resulted in a *blown-out shot*. He was burned on the arms and leg and died eight days later. H.M. Inspectors' Report, Northern Division, 1925.

(*d*) *Carelessness with naked light while handling explosives*

A Stoneman was preparing a charge for a wet hole by placing 24 oz. compressed powder in a waterproof tubing. In assembling the charge he observed a hole in the waterproof tubing. In extracting the cartridges from the tubing, contact was made with the flame of a candle. The cartridges ignited and in turn ignited 1½ lb. of compressed powder and 1 lb. of gelignite in an open canister close by. The man was badly burned and died four days later from shock following the injuries. The hole for which the charge was intended had not been drilled. *His light should* not have been *within* 4 *ft. of*

the explosive when handling it, and the explosive charge should not have been made up till the hole was ready for it. H.M. Inspectors' Report, Northern Division, 1925.

IV Miss-fires

(*a*) *Observation of statutory period in case of miss-fires*
A Shotfirer had charged a top canch shot, lit the fuse and taken refuge. Thinking it was a miss-fired shot he returned, followed by a stoneman, without waiting the statutory period of one hour. The charge exploded when he reached the canch. Both men were injured. The shotfirer died later in the day. H.M. Inspectors' Report, Northern Division, 1925.

V Permitted Explosives

(*a*) *Observation of C.M.A. rules on Permitted Explosives*
At a certain colliery safety lamps had been compulsorily introduced on account of a gas ignition. The coal gave off large quantities of gas and the workings were dry and dusty. Contrary to the C.M.A. regulations, a shot-hole was prepared *in the solid* and charged with *gelignite*. The shot was fired and an ignition of gas took place, resulting in the deaths of four persons. H.M. Inspectors' Report, Swansea Division, 1924.

THE COLLIERY FIREMAN AND HIS DUTIES.

ERRATA SLIP.

Page 75. Gas Laws. After paragraph 2 the third line should read " Where V = original volume."

Page 76. The equation should read

$$V1 = \frac{30.5 \times 200 \times (459 + 64)}{29.6 \times (459 + 52)}$$

$$= 211 \text{ cubic feet.}$$

APPENDIX I

GAS LAWS

Effect of Temperature: It is common knowledge that gases expand on being heated and contract when cooled. The fact was established by Charles at the beginning of the nineteenth century that all gases expanded and contracted equally when subjected to the same alterations in temperature. Although modern research has shown this not to be absolutely true, it is near enough the truth for all practical purposes. The effect has been formulated as follows:

"The pressure being constant, the volume of a gas increases or decreases $\frac{1}{459}$ of its volume at 32°F. (degrees Fahrenheit) for an increase or decrease of 1°F." Thus, a volume of gas occupying 459 cubic feet at 32°F. would become 460 cubic feet at 33°F., and at 60°F.,a rise of 28 degrees, the volume would be 459+28=487 cubic feet. −459°F. is known as the absolute zero and to get absolute temperature 459 should be added to the thermometer reading.

Charles' Law may be stated algebraically thus:

$$V_1 : V = T_1 : T \quad \text{or} \quad V_1 = \frac{T_1}{T} \times V$$

Where V_1 = original volume
V_1 = new volume
T = original absolute temperature
T_1 = new absolute temperature

Effect of Pressure: The volume of a gas is affected also by variations in pressure. The law governing the volume of a gas with relation to pressure was set down by Boyle, and may be stated as follows: "The volume occupied by a given weight of any gas is inversely as the pressure, if the temperature is constant." Thus, if the pressure is doubled, the volume is halved, and if the pressure is halved the volume is doubled.

In the form of an equation, this law is

$$V_1 : V = P : P_1 \text{ or } VP = V_1P_1$$

Where V = original volume
V_1 = new volume
P = original pressure
P_1 = new pressure

Combining these two laws algebraically, we get the formula

$$\frac{PV}{T} = \frac{P_1V_1}{T_1}$$

Example: A volume of gas occupies 200 cubic feet at 52°F. and 30·5 inches pressure. Find its volume at 64°F. and 29·6 inches pressure.

$$\text{Since} \quad \frac{PV}{T} = \frac{P_1V_1}{T_1}$$

$$\text{then} \quad V_1 = \frac{PVT_1}{P_1T}$$

Substituting the values

$$V_1 = \frac{29{\cdot}6 \times 22 \times (459+64)}{30{\cdot}5 \times (459+52)}$$

$$= 211 \text{ cubic feet.}$$

Diffusion of Gases: If a vessel, filled with a light gas such as hydrogen, be placed mouth to mouth over a vessel containing the much heavier gas oxygen, it will be found after the lapse of a little time that the two gases have mixed to some extent, although the oxygen is sixteen times as heavy as the hydrogen. In the course of time, a uniform mixture of the two gases will be found in both vessels. This passing of one gas into another without mechanical aid is called diffusion. Diffusion of gases will take place even when the gases are separated by a porous medium such as unglazed earthenware or plaster of Paris.

As a result of his experiments, Graham enunciated the law: The relative rates of diffusion of any two gases are inversely as the square roots of their densities.

A practical illustration of the diffusion of gases through a porous medium is sometimes found in a mine. A regulation mortar-faced stopping may be erected in a cross-cut between a main road and an old companion road. The mortar-faced end will be on the main road side and may be set back some few yards into the cross-cut. If gas accumulates in the old road, it will probably diffuse through the stopping and render the recess on the main roadside a place of great danger. Such places should receive frequent examination.

Once gases have diffused into each other, they will not separate again without outside aid.

APPENDIX II

Schools, Institutions and Authorities Approved for the Purpose of Granting Certificates to Firemen, etc., and to Shotfirers.

SCOTLAND

Heriot-Watt College, Edinburgh
Royal Technical College, Glasgow

NORTHERN DIVISION

Cumberland Education Committee
Durham County Education Committee
Newcastle-upon-Tyne Education Committee
Northumberland Education Committee
Yorkshire—North Riding Education Committee

YORK AND NORTH MIDLAND DIVISION

Barnsley Education Committee
Batley Education Committee
Cleckheaton Technical Institute
Derbyshire Education Committee
Dewsbury Technical School
Doncaster Education Committee
Huddersfield Technical College
Leeds Education Committee
Nottinghamshire Education Committee
Rotherham Education Committee
Sheffield Education Committee
Sheffield University
University College of Nottingham
Wakefield Education Committee
Yorkshire—West Riding Education Committee

LANCASHIRE AND NORTH WALES DIVISION

Accrington Education Committee
Ashton-in-Makerfield Urban District Council Higher Education Committee
Atherton Urban District Council Higher Education Committee

Burnley Education Committee
Flintshire Education Committee
Leigh Education Committee
Manchester Municipal School of Technology
St. Helens Education Committee
Tyldesley Higher Education Committee
Wigan and District Mining and Technical College
Worsley Urban District Council Higher Education Committee
Wrexham School of Science and Art

SOUTH WALES DIVISION

Breconshire Education Committee
Glamorganshire Education Committee
Carmarthenshire Education Committee
Merthyr Tydfil Education Committee
Monmouthshire Education Committee
Swansea Local Education Authority

MIDLAND AND SOUTHERN DIVISION

Birmingham University
Derbyshire Education Committee
Gloucestershire Education Committee
Kent Education Committee
Oswestry Technical Institute
Somerset County Education Committee
Stoke-on-Trent Education Committee

APPENDIX III

Date: 18th May, 1927. *Seam: Jewel.*

Road or part of road examined (1)	Time of Examination (2)	Condition as to Coal dust (3)	Entries in preceding columns certified correct (*Person making Examination to sign here*) (4)	Steps taken to mitigate danger arising from coal dust. (*To be filled in and initialled by Manager or Under Manager*) (5)
Riley's dook	9.30 *a.m.*	*Roads and faces damp—no coal dust.*	*Wm. McDonald*	
East level and headings	10.30 *a.m.*	*Girders and Timbers in level require cleaning.*	*Wm. McDonald*	*Two men on afternoon shift instructed to remove dust from girders and timbers in East level. Two bags of stone dust supplied for application.*

Countersigned ..... *Under Manager* *Date*.....

..... *Manager* *Date*.....

REPORT OF INSPECTION BY FIREMAN, EXAMINER OR DEPUTY

Giffbank Mine. *Jewel Seam.*

Date: 18*th May*, 1927. *East Level District.* *Day Shift.*

Strike out words in italics for report of inspection during shift.

I hereby certify that I have inspected every part of the mine situated beyond the *appointed* Station, and in which workmen are to work or pass during the shift, *and all working places in which work is temporarily stopped within any ventilating district in which the men have to work*, and that the following is a full and accurate report of the condition of the district as ascertained by me during my inspection:—

Noxious or Inflammable Gases..	*A small accumulation of firedamp was found near the face of the brushing in No. 5 branch road in Riley's dook at 5.45 a.m. This was clear at 6.40 a.m. by adjustment of brattice hurdle. All other places free from gas.*
State of ventilation	*Good. New brattice required on screen in No. 3 heading.*
Condition of roof and sides ..	*Safe except at entrance to No. 3 heading which is under repair.*
Supply of timber—	
(*a*) Working places ..	*2′ 6″ props required in machine run in Riley's dook.*
(*b*) Pass-byes, sidings, etc...	*Sufficient.*
Other matters affecting safety, and remarks	*Satisfactory.*

To be filled in for inspection **during** shift only.

To be filled in for inspection **before** shift only.

- - Number of men under my charge during the shift, as checked by me: 43

Examination: Commenced 5-30 *a.m.*; Completed 6-50 *a.m.*

Time of commencement of work in the shift: 7-0 *a.m.*

Signed: *Wm. McDonald.*
Fireman, Examiner or Deputy

Date: 18*th May*, 1927.

Countersigned ..... *Date* .....
Under Manager.

Countersigned ..... *Date* .....
Manager.

Month: May. *Seam: Jewel.* *District: East Level.*

Day of Month (1)	No. of Shots charged: No. of Shots fired exclusive of Miss-fires (2)	No. of Shots charged: No. of Miss-fired Shots (3)	No. of Shots charged: Total (4)	No of Shots charged, whether fired or miss-fired, consisting of: 1 cartridge (5)	2 cartridges (6)	3 cartridges (7)	4 cartridges (8)	(9)	Remarks (10)	Signature of Shotfirer (11)
1	8	*None*	8		6	1	1			*Wm. McDonald*
2	7	*None*	7		5		2			*Wm. McDonald*
3										
4										
5										
6										
7										
8										
9										
10										
11										

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THE following booklets may be had upon application

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"Blasting Explosives and Accessories"

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"Blasting in Collieries and Hints on Electric Shotfiring"

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